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OKLAHOMA STATE UNIV STILLWATER ELECTRONICS LAB
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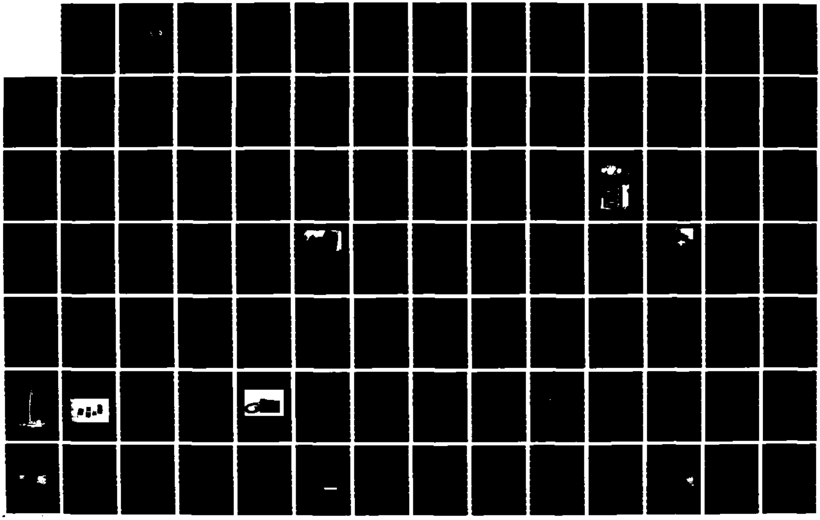

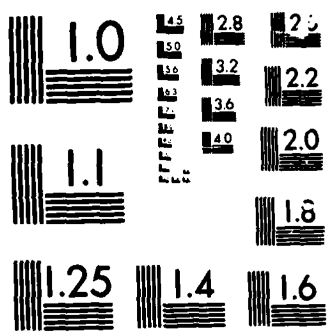
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INSTRUMENTATION RESEARCH AND SUPPORT SERVICES

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This report summarizes upper air research support services supplied to the Air Force Geophysics Laboratory. These services include design and construction of both air-borne and ground based equipment, as well as the supply of personnel and related equipment at a number of remote sites. Both analog and digital systems are described. Related activities have included studies and research activities directed toward anticipated future requirements for support.

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SUMMARY

The Electronics Laboratory has supplied ongoing engineering and support services to the Air Force Geophysical Laboratory under contract F19628-81-C-0079 for the past 54 months. These services have been provided in support of the general program of upper air research pursued by the sponsoring agency, and have been a continuation of similar services provided by this group under previous contracts. Activities have primarily been associated with the use of instrumented rocket vehicle payloads to investigate various parameters of the earth's atmosphere. This report reviews the overall background and history of this program, and provides details concerning various services which have been supplied.

Services normally begin with a study and definition of the specific technical requirements which will govern design of the electronic systems to be used with a given payload. This is followed by development and construction of airborne or ground support equipment which meets these requirements, as verified by qualification tests which are made to insure compliance with the defined specifications. The complexity of the programs required to qualify modern high speed PCM subsystems has led to the development of automated testing under control of a microcomputer, which permits elaborate sampling and analysis with hard-copy printout of test results; such equipment is described. After completion of local testing, the equipment is delivered to the using agency and further assistance is provided when installing the equipment within the payload, integrating all elements into an operational system which is tested under conditions simulating those to be anticipated during flight. Assistance is continued as the payload and support equipment is taken to the launch site and prepared for flight. Mission support includes a detailed sequence of prelaunch tests and extends through the actual launch; data from the vehicle in flight is received, displayed for quick-look evaluation, and recorded for later analysis. In some cases, the support may also include determination of the vehicle trajectory, or require post flight data analysis.

Because most of the instruments now being flown are quite sophisticated and capable of resolution and accuracy which exceed the capabilities of analog telemetry systems, a major area of support has been design and construction of appropriate digital telemetry systems which can accommodate the high sampling rates and measurement precision of a complex array of instruments which must acquire and transmit large volumes of data in a relatively short measurement time. This requirement has led to the development of

complementary PCM terminal equipment in the ground support complex, and existing equipment from previous tasks has frequently been updated and modified to enhance utility during tests and in the field support mission. Some of this peripheral GSE is also described.

The existing autotracking antenna systems and associated TRADAT equipment which provides trajectory information (by combining pointing angles with slant range measurements) have also been modified to adapt the same technique to use with asynchronous PCM telemetry downlinks. The uplink command capability has been retained in the experimental system described.

Concurrent with mission support services, a program of research and development activities which may have potential future applications to this program has been pursued. These activities are also included in the report.

ACKNOWLEDGEMENT

In a report such as this, which must cover many different areas of work on a multiplicity of related projects which have continued over a considerable span of time, the "author" is more accurately described as an editor whose primary function is gather and compile the data provided from those individuals who bore the actual responsibiliity for the work, now being reported after the fact. In recognition of this situation, the first acknowledgment must be given to all those contributors whose names appear on the following page; without their efforts no report would be forthcoming, and gratitude is wholeheartedly expressed to each of the dedicated staff members who so unselfishly demonstrated their desire that each task assumed was completed on time and to the very best of their ability.

All work discussed within this report has been done under the sponsorship of the Aerospace Instrumentation Division of the Air Force Geophysics Laboratory, and this sponsorship is gratefully acknowledged. Special thanks go to the Contract Managers: Mr. Jack R. Griffin and his successor, Lt. William E Day III, both from the Sounding Rocket and Mechanical Engineering Branch of the sponsoring agency. Both have provided valuable leadership and vitally needed continuity to an exceptionally complex set of projects during a period in which changes of priorities have demanded unusual flexibility in scheduling and conscientuous re-evaluation of those objectives of maximum importance to the overall program.

Appreciation is also expressed to virtually the entire staff of the sponsoring group. Their cooperation in providing timely assistance and updated technical information concerning all phases of our effort has contributed much to our ability to deliver the services desired in full accord with the rigorous time schedule required. Their overall attitude of providing a team approach to solutions of complex technical problem areas has been a vital factor in maintaining continuity for the main mission of Upper Air Research.

Thanks must also be offered to all participating individuals of the many associated agencies, from both government and private industry, who have been involved in the period of services reported herein. They have all worked together to ensure that all aspects of the research program have fit smoothly into a coherent effort which culminates in the successful launch of each vehicle carrying a scientific instrument, wherever the selected launch point may have been and whatever the problems which may have arisen unexpectedly to place the mission in jeopardy. The dedication displayed remains a most remarkable aspect in this field of endeavor and must leave the observer with an overpowering sense that the importance of the objectives sought always transcends the considerations of personal inconvenience or of more conventional narrow organizational limits of responsibility.

LIST OF CONTRIBUTORS

The following staff members of the Electronics Laboratory, Oklahoma State University (College of Engineering, Architecture, and Technology) have contributed to the work described in this report. All contributors are listed alphabetically.

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1.0 INTRODUCTION

This report describes the services supplied to the Air Force Geophysical Laboratory (AFGL) under DOD contract F19628-81-C-0079. Work performed by the Electronics Laboratory of the Oklahoma State University was in the form of a variety of engineering support services, provided for instrumentation which was required in the AFGL Upper Air Research program. These services included the direct support activities required for a number of instrumented rockets and balloons which were used for measurements of various parameters within the earth's atmosphere. Some research and development programs were also involved; these were directed toward investigations of direct interest in future projects planned under the same program, and have frequently led to the design of special hardware, either for airborne elements or as special ground support equipment to be used in the same program. Payload support systems were designed and assembled, using a combination of commercial components and custom-built items provided by the Electronics Laboratory. Each such system was tailored to provide the optimum features desired for the primary scientific measurements of interest in the mission for which the payload was planned. In addition to these services, provided at the base laboratory in Stillwater, Oklahoma, many related field services have been supplied at a number of locations. Manpower and equipment have been provided to assist in test and operation of the scientific payloads. These services have covered both integration testing of the systems to be flown, and later preflight tests at the actual launch site. In the majority of launch missions, data has been received from the vehicle carrying the payload during the actual flight, and this data is both displayed for analysis of performance and recorded for following data reduction after flight.

1.1 Previous Related Work:

The Electronics Laboratory has previously supplied similar services to AFGL through a number of engineering support contracts. Initial services were begun in the early rocket program at the White Sands Missile Range (WSMR) in New Mexico, and were originally associated with tracking the payloads during flight in order both to retrieve telemetry data and to provide raw data for trajectory calculations. This work was soon supplemented by additional services which not only continued and refined the data reception and trajectory determinations, but also added the design and fabrication of airborne and ground subsystems for use in the overall program. A series of contracts has followed, generally each of approximately three years duration. This succession of contracts has maintained continuity in the overall AFGL program and enhanced efficiency in the support effort, since it has made maximum use of the previous

experience gained in this work and utilized the knowledge of planned future programs to plan upgraded facilities and to devolop new items for later application. The most recent contracts preceding the the current effort, dates in which they were in effect, and the final reports which documented the services supplied have been as follows:

F19628-72-C-0139:	February 1972 - January 1975	(Ref. 1)
F19628 75-C-0084:	January 1975 - July 1978	(Ref. 2)
F19628-78-C-0033:	March 1978 - February 1981	(Ref. 3)

The main body fo the report which follows will include specific references to preceding contracts which initiated action on those projects which have continued into the work now being reported. Much of the work which has been initiated under this current contract will also be continued under the next following contract.

1.2 Contract History

In response to solicitation number F19628-81-R-0057, the Electronics Laboratory submitted on 2 January 1981 our Engineering Research Proposal number EN81-R-62-0, offering to provide a three-year period of services at an estimated total cost of $2,214,540. Subsequent negotiation eventually redefined the exact services to be supplied and resulted in Contract F19628-81-C-0079, with an effective commencement date of 13 February 1981 and a maximum total cost of $2,322,200 for 36 months of support services. Initial incremental funding was established at $405,355 for the remaining period of the first fiscal year; amendments P0001 and P0002 later increased the funds allocated for services during FY-81 to a total of $471,355. Amendments P0003 through P0007 and P00010 were executed as administrative amendments, and called only for changes in the Special Test Equipment to be acquired, the reporting requirements for the contract, and the proper order for fund expenditure. Amendments P0008, P0009, and P00011 through P00015 subsequently provided additional incremental funding to make a total of $1,272,955 available for services to the end of FY-82, and made some changes in the equipment and service requirements during this same period. The increased effort called for during this period also resulted in renegotiation of the total estimated cost of support services for the entire contract period, and established a new ceiling value of $2,357,730. Additional amendments P00016 through P00030 made further administrative changes and also provided additional incremental funds, increasing the funding available to $1,824,955 for services through FY-83. Amendment P00030 also established the first incremental funding for use during FY-84, and subsequent amendments P00031 through P00046 provided additional FY-84/85 funds up to the full value of $2,551,193.01.

Administrative changes redefining the Principal Investigator and services desired were accomplished during this period, and services were extended through 30 June 1984, with the final reporting sequence correspondingly extended through 30 September 1984.

1.3 Contract Objectives.

Laboratory work and engineering services to be supplied under this contract were quite diverse in the period covered. They were defined in general terms in the basic contract under Part II, the Schedule; Section F, Description/Specifications. (This general "Statement of Work" was supplemented throughout the life of the contract by written descriptions and specifications to provide more detailed requirements for individual projects.) The contract required the Electronics Laboratory to supply all necessary personnel, facilities, services, and material to accomplish the tasks described below, as quoted from the above referenced section of the contractual document:

"Line Item 0001 - Provide engineering and technical support for instrumenting fifteen (15) research probes, ground instrumentation support for thirty-six research probes, instrumentation and tests concerning telemetry, tracking and associated instrumentation systems, and continuation of the development of a system to provide trajectory information through the telemetry system and development of specialized Ground Support Equipment (GSE). Work shall be performed in accordance with the Contractor's Technical Proposal Number EN81-R-62-0, dated 81JAN02 and the following Sub-Line Items:

Sub-Line Item 0001AA - Instrument fifteen (15) research probes (rockets, balloons or satellites) for data transmission and reception and trajectory determination as follows:

a. Modify, fabricate, test and install airborne equipment.

b. Perform integration tests at AFGL, to insure compatibility with the experiment and with simulated range instrumentation.

c. Support environmental tests at AFGL.

d. Support tests at range during preparation and launch. Launches will be at sites to be designated by the Contracting Officer and will include but not necessarily be limited to Churchill Research Range, Canada; Poker Flat Research Range, Alaska; White Sands Missile Range, NM; NASA Wallops Island, VA; Vandenberg AFB, California; Kwajalein Missile Range, Marshall Islands; Woomera Research Establishment, Australia.

Sub-Line Item 0001AB - Provide services toward operating ground based instrumentation systems in support of thirty-six (36) probe launches at ranges to be designated by the contracting Officer as listed in Sub-Line Item 0001AA d. as follows:

a. Maintain and operate ground based data reception and recording equipment.

b. Devise improvements to existing equipment to meet special requirements.

Sub-Line Item 0001AC - Conduct studies, investigations and tests concerning real time data presentation, magnetic tape recording and telemetry instrumentation systems that will lead to improved technique/or designs for AFGL's Research Rocket Program.

Sub-Line Item 0001AD - Improve: a) ranging through PCM telemetry systems developed under Contract F19628-78-C-0033; b) Command through ranging up leg link and expand to provide a minimum of 128 discrete commands.

Sub-Line Item 0001AE - Develop specialized Ground Support Equipment (GSE) and data display equipment as required to support field operations of the Background Measurements Program (BMP), Multi Spectral Measurements Program (MSMP) and the AFGL environmental research program.

Line Item 0002 - Data in accordance with Contract Data Requirements List, DD Form 1423, dated 80JUL01 attached hereto and made a part hereof."

1.4 Other Related Work

Some of the work performed under this contract (particularly field support service) was an extension of tasks initiated under preceding AFGL contract F19628-78-C-0033, which overlapped the beginning of this contract and already had missions underway at the launch sites when this work began. In addition, continuing efforts under the MSMP and Balloon Airborne Mosaic Mapping (BAMM) programs were initiated under sponsorship of the earlier F19628-75-C-0084 contract. Ongoing programs for tracker and trajectory system development had originated even earlier under AFGL sponsorship, and have been continued when changes in the state of the art indicated that system update was desirable. Following the same philosophy, many of the projects which were initiated late in this contract period may be expected to continue under sponsorship of the next following AFGL contract to be negotiated in this sequence.

Related work, supported from outside funding under other Subcontracts or Purchase Orders, also proceeded in conjunction with or during the period in which services were supplied to AFGL under F19628-81-C-0079. This work has included all of the projects listed below.

1.4.1 "Mobile Telemetry Tracking Systems (MTTS)".

Six MTTS ranging systems were built under NASA sponsorship (Contract NAS6-2970; 2 February 1979 - 31 May 1981). This project originally called for four modified TRADAT systems, similar to the AFGL TRADAT V design (Ref. 4), but modified for interface with existing NASA autotrack antennas and incorporating a number of specific changes to meet the NASA requirements for their use. Uplink ranging code transmitters were provided in both amplitude modulated (AM) and frequency modulated (FM) versions, and were provided for selectable carrier frequencies of 547, 550, or 553 Mhz, as specified by NASA. Other variations also existed in both the hardware and software supplied with these systems, which included a number of NASA flag monitors in the coded data train. These systems were designated as the TRADAT Model N-1, serial numbers 1 through 4. A later modification to this same contract called for two additional such systems to be added, but with some changes in the detailed specifications for the later versions, which were to be modified for use with special Minitracker antenna systems, also built by our organization under the project described in 1.4.2 below. The last two systems were designated as the Model N-2 versions of the TRADAT system. Details for both types of systems are detailed in References 5 and 6, the Technical Manuals which were supplied for use with these systems.

1.4.2 Model N-1 Minitrackers.

Two special versions of the Minitracker autotrack antenna system were also built for NASA under a separate contract (NAS6-3103) during the period from 12 May 1980 through 11 January 1982. As in the case of the MTTS systems, these were NASA variations on the original AFGL Minitracker system (References 7 and 8), which has been reported previously. The NASA version was modified to use a 6-foot diameter parabolic reflector in the receiving system, which increased gain at the expense of a larger and heavier design with narrower acquisition beamwidth. Provision for reception in three different radio frequency bands was added in the form of three independent selectable down-converters, which gave coverage for bands of 1435 - 1540 MHz, 1650 - 1710 MHz, or 2200 - 2300 MHz. The band selected was converted to the 215 - 320 MHz band by a down-converter housed within the antenna pedestal (which had been enlarged to permit installation of the larger parabolic reflector), and thus operated at P-band for

compatibility with the existing NASA receiving equipment. The RF feeds were special wide-band versions to accomodate the desired bands for received signals, and special wide-band preamplifiers and filters were added within the RF feed assembly for the same purpose. Because the associated uplink ranging signals for the TRADAT equipment also differed from the AFGL version, an entirely new uplink antenna design was developed and two different versions were supplied: one for the earlier 403/430 MHz AFGL version, and a second for use with the later NASA 547 to 553 MHz systems. The new uplink antennas were more compact and designed to mount directly in front of the RF feed assembly, thus reducing parallax effects and obviating the need for the previous cumbersome boom mount. System details were documented in the associated technical manual (Ref. 9) which was provided for the NASA users.

1.4.3 Space Vector Corporation (SVC) PCM Encoder.

A special PCM telemetry encoder was constructed for the Space Vector Corporation, of Northridge, California. This work was done in period of February through April, 1982, under SVC Purchase Order number 020289. The system was designed for use during the test and launch of the experimental Aries-class vehicle, Conestoga I. The unit was based upon an earlier similar system developed for use with the Target Engine Module (TEM) in the MSMP program (Ref. 3, section 4.1). Changes were made to provide a Bi-Phase Level system operating at 192 Kilobits/second, with 8-bit resolution and a sample rate of 2000 frames per second. Twelve words were used per minor frame, and provided subcommutation in seven of the words through a major frame length of forty minor frames. Word zero was standard Barker code frame synchronization, word one provided binary-coded sub-frame identification (SFID), word two was generated from analog multiplexed data (synchronized with frame rate) from forty temperature sensors in the aft portion of the vehicle, and words three through eight were assigned for low-speed housekeeping data. These six words each repeated a sequence of eight inputs five times within the full major frame. The remaining three data words provided high speed data sampling at minor frame rate.

1.4.4 SVC Support Services.

Field support services were also supplied to SVC during the launch of the Conestoga I vehicle, for which the above PCM encoder was built. Under SVC Purchase Orders numbers 020959 and 020960, one man was supplied at the Matogordo Island, Texas, launch site during the test and launch sequence. These services provided assistance in PCM data reception, display, and recording during the period of September/October, 1982.

1.4.5 Utah State University (USU) Support Services.

Additional support services related to this contract were supplied to the Utah State University in connection with planning for the flight of the BAMM IIa payload, under USU Purchase Order 08414 in September of 1983. One engineer was supplied as a consultant in evaluation of the requirements for proposed changes to the telemetry system and associated ground support during a review meeting at the Physical Science Laboratory (PSL) in New Mexico. These services were supplied while related work under the primary AFGL contract was at a standstill due to funding limitations late in FY-83. This maintained continuity in the planning for both organizations, since the individual provided was also the responsible engineer for the Electronics Laboratory portion of the same work.

1.4.6 CIRRIS C1A Simulator.

A special purpose PCM simulator was constructed for the Wentworth Institute of Technology (WIT) under their Purchase Order 28690. This device was designed and built to simulate the PCM format to be used in the CIRRIS C1A project; design was in accord with specifications supplied from AFGL. The simulator provided two output data streams, synchronized with common bit and word clock timing. Each output simulated the anticipated data streams to be expected from the flight instrument.

The radiometer simulation section included the common clock and timing circuits. the output data stream was NRZ-L at 352 Kbps and made up of a minor frame of forty 16-bit words, with subcommutation available through a major frame length of 96 minor frames. In addition to the required major frame synchronization (words zero and twenty) and SFID (word five), the format included incrementing time signals to simulate the IRIG B time words of the C1A instrument. These were generated by counting down from the internal crystal controlled clock oscillator to generate seconds and minutes, while hours were inserted from switch selectable coding under control of the operator, and days were a fixed code. (All time words were inserted in the proper place in the format.) A simulated housekeeping subcommutated signal was derived from the same frame counter used to generate SFID and provided a ramp signal to word ten. This provided a 64-step ramp, followed by a 32-step ramp, for the simulated housekeeping data in each major frame. A synchronized sinusoidal analog signal, simulating the chopper reference, was also generated internally and converted to digital format for inclusion within the frame (using a 12-bit A-to-D converter, with four zero bits as fill). This same converted analog signal was used to simulate synchronized high and low gain detector output signals, by appropriate bit shifts in timing of the bit stream. Synthetic digital words for control

monitor box signals were generated from hard-wired parallel input shift registers and inserted in the proper places in the data stream.

The associated interferometer simulator section was synchronized through use of common bit and word clock signals, generated within the radiometer section. Format was again NRZ-L, this time with 120 sixteen-bit words per minor frame and 48 minor frames per major frame to permit subcommutated words within the data stream. The same synthetic time signals generated in the radiometer section were again inserted at the proper times to represent IRIG B within the format, and both the 32-bit frame sync and 16-bit SFID words were generated as required. Five separate shift register digital word generators provided recognizable uniquely coded signals to simulate photometer, housekeeping, and gimbal monitors, as well as the filter wheel/black body and retrace ID words. The housekeeping and gimbal words were constructed from incrementing ramp signals, generated in a manner similar to that described for the radiometer section and thus synchronized with the major frame. An "Analog Input" signal jack permitted externally provided signals to be processed in order to provide a common "Detector Data" word as the major data signal for this section. The same analog input signal, fed through a low-pass filter, provided the "DC Ground Reference" level signal for words 13 through 17. Multiplexers synchronized with word and frame rate addresses selected either the "Data" or "DC Ground Reference" versions of the external analog signal at the appropriate times for use, in accord with the desired output format. The processed analog signal for either form was then converted to digital form through a bi-polar 12-bit A-to-D converter.

Internal power supplies operating from 115 volt AC power provided all required operating voltages; the system was built for relay rack installation with a standard 19 inch wide panel, 5.25 inches high, and was twelve inches deep.

2.0 TRAVEL AND RELATED ACTIVITIES

Support provided to the AFGL program under this contract has required travel to a number of sites remote from the base location of the Electronics Laboratory in Oklahoma. The effort expended in this area of our support has been substantial; 1576 man days of travel have been required. Seventy-six trips have been made to twenty-five separate sites (eight of which lie outside the continental limits of the United States) in support of twenty-five different programs. The travel may de divided into three major categories: that done for coordination and planning for future programs, that done for integration or payload testing to insure proper operation of the equipment prior to beginning the actual launch mission, and travel required to the launch site for prelaunch testing and support during the actual launch mission. Some additional travel is also undertaken for miscellaneous reasons. Technical details of activities pursued in specific projects are discussed in later sections of this report; this section provides only brief comments concerning the individual sites visited, effort expended, and programs which were supported by the travel activities.

2.1 Coordination and Planning Meetings.

In addition to the coordination and planning which was routinely accomplished in connection with integration and launch travel, these activities have required twenty-seven special trips with a total duration of 152 man days. Twelve sites have been visited; eleven different programs have been involved. Locations and purposes for the travel were as follows:

2.1.1 Fourteen trips requiring 73 Man days of travel were made to the AFGL facility at Hanscom Air Force Base, Massachusetts. One trip required four man days in preliminary coordination and planning for the Brazilian Ionospheric Modification Experiment (BIME), later conducted from the Natal Rocket Range (NRR) in South America. A second trip of seven man days effort was made in establishing the technical requirements for equipment and support of the High Performance Target Engine Module (HPTEM) project under the Multispectral Measurement Program. A third trip involved one man for three days in attendance at a technical design review meeting for planning the requirements to be required in support of the Polar Ion Irregularity Experiment (PIIE) project. Five trips required three men for a total effort of forty man days for preliminary coordination discussions concerning details anticipated for the planned Large Array Infrared Telescope (LAIRTS) and High Altitude Recovery Program (HARP) activities during the continuation of present obligations. Another trip also required two men for ten man days in accomplishing the program plans for the Spacecraft Contamination Orbital Research

Experiment (SCORE) which was expected to utilize a platform within the Space Shuttle. One other trip required four man days of effort in preliminary coordination and planning for the LAIRTS mission, also being scheduled for a later flight aboard the Space Shuttle. One additional trip requiring six days at this facility was in connection with the BERT II feasibility study.

2.1.2 Travel on the part of one man to the NRR in Brazil for a site visit and discussion of support requirements for the BIME project required twelve man days of effort prior to the launch support later provided at the same site. A second trip of ten days duration to the same site was for review of the forthcoming requirements for the HARP program.

2.1.3 One trip of six man days was made to Sao Jose dos Campos in Brazil in connection with coordination and planning for the later High Altitude Recovery Program (HARP), which was also planned for the NRR site.

2.1.4 Two trips were made to the Physical Science Laboratory (PSL) site in Las Cruces, New Mexico for Design Review Meetings and coordination for the BAMM II program. Eight man days were required in this support.

2.1.5 One other trip of three man days duration was made, to Roswell, New Mexico, in support of the BAMM II program. Planning was both for the BAMM mission and discussion of the new system for PCM ranging, which was to be test flown aboard a balloon vehicle.

2.1.6 In connection with travel reported in 2.5.1 of this report, a side trip of one man day was made to the Goddard Space Flight Center (GSFC) in Maryland, for the purpose of coordinating support requirements for the flight of an AFGL wide-band TV camera aboard NASA rocket 27.045UE. This project, to be launched from the Fort Churchill facility in Canada, used an S-band frequency for which support facilities were not available in the Canadian launch complex; tests of the overall payload (including the AFGL portion) were performed during this same trip.

2.1.7 One man was provided for three days at the Santa Barbara Research Corporation in California, to attend technical meetings held to define the preliminary approach to data acquisition from the extremely complex array of sensors in the LAIRTS instrument.

2.1.8 One man was supplied for three days at the University of Wyoming, in Laramie, for continuing discussions on the requirements for the LAIRTS data Formatter.

2.1.9 A special trip was made to the Utah State University facility in Logan, Utah, to attend a conference concerning the CIRRIS IA data formatter.

2.1.10 The BERT II feasibility study also required travel on the part of one man to two additional sites: eight days were involved in evaluation of power supply requirements at the Westinghouse Defense Electronics Center in Baltimore, Maryland, while a second trip involving three days was required for study of proposed flight equipment, demonstrated at Los Alamos, New Mexico.

2.2 Integration and Payload Tests.

A number of trips were required in support services in which personnel and equipment were supplied to AFGL for prelaunch testing of payloads or components which were scheduled for later launch under this contract. In each instance, airborne equipment previously fabricated at the OSU base laboratory was mated with and tested in conjunction with other portions of the overall payload. These tests were made to assure that all equipment was compatible, both mechanically and electrically, and performed in the desired manner. A form of environmental testing usually follows preliminary operational bench tests, in which the flight equipment undergoes shock and vibration testing while assembled. Occasionally other qualification tests are also performed in conjunction with the integration tests. Although these tests are most frequently performed at the AFGL facility, some may be conducted at outside facilities for the convenience of the agencies involved, or because special equipment needed for the test program is available elsewhere. Tests of this type required eighteen separate trips to four different sites; 139 man days of such effort were supplied in support of eleven different programs during this contract period.

2.2.1 Nine trips were made to AFGL for eight different programs in this type of support, requiring the expenditure of 90 man days of effort. One trip of thirteen man days was made on the BAMM II program, in preparation for the later launch of balloon H82-11 from Chico, California. Two other trips with a total effort of seventeen man days were made in conjunction with the falling sphere program; integration testing here covered four separate piggy-back payloads which were to be launched in three different programs. Sphere AC-15 was tested for use in the TRACER program to be launched from the NASA Wallops Flight Center, sphere AC-16 for the Cold Arctic Mesopause Project (CAMP) scheduled from the Esrange launch facility in Sweden, and spheres AC-8 and AC-18, planned for use in the Middle Atmosphere Program/Winter in Northern Europe (MAP/WINE) and to be launched from the Norwegian Andoya Rocket Range (ARR). (One additional sphere, AC-17, was also provided for the Structure and Atmospheric Turbulence Environment project at the Poker Flats Research Range (PFRR) in Alaska, but the integration tests for this payload were conducted without assistance

from the Electronics Laboratory.) Two separate trips, requiring a total of thirty man days, were made for the purpose of testing the BIME payloads on rockets A19.124-1 and -2, which were later launched for the NRR site in Brazil. Another trip required the services of one man for five days in tests preceding the CN2 series of balloons to be launched from the National Oceanic and Atmospheric Administration (NOAA) facility in Colorado. This was rather an unusual test activity, in that the integration tests included the launch of two thermosonde balloon payloads from Hanscom Air Force Base prior to proceeding with the actual field trip to the Colorado launch facility. One additional trip requiring seven man days was made in preparation for the launch of the A24.7S2-2 payload later from the WSMR facility under the Far Infrared Spectral Survey Experiment (FIRSSE) portion of the Background Measurement Program (BMP) which was underway at the time this contract began. Two other trips, totalling eighteen man days, were made in connection with integration and vibration testing for the PIIE payload.

2.2.2 Six different trips totalling twenty-nine man days were made to the Space Vector Corporation (SVC) facility in Northridge, California. These trips included air-bearing tests and payload integration for two different Aries programs. Four trips with a total effort of 21 man days were required in connection with the TEM-3 payload, leading up to the later launch of A24.609-3 from the WSMR facility. One other trip to the same facility was required in the Earth Limb Clutter (ELC) program, testing the payload later launched aboard A24.260 from WSMR. One additional trip of four days duration was made in order to install temperature sensors in the HARP payload.

2.2.3 One trip requiring six man days was made to the Ball Aerospace Corporation (BAC) facilities in Boulder, Colorado. This trip was done in preparation for the FIRSSE payload, later launched on A24.7S2-2 from the WSMR facility in New Mexico.

2.2.4 Two trips were made to the PSL West facility in Las Cruces, New Mexico. Both were done in preparation and testing of the BAMM payload, once prior to the Roswell, New Mexico, launch and the second in preparation for the Chico, California, launch mission.

2.3 Launch Support Activities.

As has been the case in previous contracts for support of the AFGL research program, the majority of the field services supplied were in direct support of launch missions at remote sites. Major logistic problems were encountered in some of these activities because of the quantity of support equipment which was needed at remote sites outside the contiguous forty-eight states. In general, the launch support activities have included

such items as pre-launch testing, operation of portions of the payload which were constructed at the Electronics Laboratory, operation of relatively elaborate ground support complexes to display and evaluate performance, reception and recording of data during flight, and post-flight data analysis and reduction of data. In some cases, autotrack antenna systems have been used both for data reception and, in conjunction with trajectory determination equipment, to provide the flight trajectory data for the vehicle or payload. Command capability is also occasionally provided from the OSU station. Thirty-five trips, requiring 1302 man days of effort, have been made to twelve different sites (seven of which were overseas) in support of eighteen projects. These activities have resulted in the launch of 24 major rocket payloads and 23 balloon payloads; four additional rockets and one balloon payload were supported, but launch was postponed after supply of prelaunch support. In connection with the major payloads, additional assistance was provided for associated launch of a number of small meterological rockets in several of the missions.

2.3.1 Travel to the PFRR facility in Alaska has required twelve trips and used 413 man days of support for twelve major payloads; nine of these were finally launched and three others were postponed because the desired geophysical conditions were not obtained during the assigned launch windows. One trip of 23 man days was devoted to completion of the Auroral Energy project, begun under preceding contract F19628-78-C-0033 and still underway when this contract was initiated. Rockets A13.020, A13.030, A13.031, and A10.903 were successfully launched in this project. Six separate trips requiring 134 man days of support were provided for the Solar Proton Event (SPE) project in several successive seasons. Although A10.901-2 was eventually launched, A10.903-3 and -4, together with A14.021-2, were postponed and may yet be rescheduled for another season. Two trips with a total support requirement of 128 man days were devoted to launch of the Earth Limb Infrared Atmospheric Structure (ELIAS) payload, which was finally launched on the second trip. (This trip also overlapped one of the support efforts for the Field Widened Interferometer (FWIF) payload.) Two additional trips and 118 man days of support were provided for the FWIF project, in which payloads A30.175 and A30.276 were eventually launched. One final trip to this site was for the ten man days of support provided for the STATE project, during which A11.074 was launched. A number of small met rockets were also supported during this mission.

2.3.2 Travel was required to the WSMR site in New Mexico for complex Aries class rocket payloads in five different programs. Twelve trips and 265 man days of support were provided. The MSMP program required four trips with a total duration of 56 man days in support of the TEM-3 payload, launched on the A24.609-3 rocket. The remaining

trips to this site were all required under the BMP program: Three more trips and 67 man days of effort were supplied for launch of the FIRSSE payload aboard A24.7S2-2; two trips totalling 60 man days preceded the launch of the Zodiacal Infrared Project (ZIP) payload aboard A24.6S1-2; two trips and 46 man days effort were required in support of the Survey Probe Infrared Celestial Experiment (SPICE) payload launched on A24.7S2-3, and the ELC payload launched by A24.260 required one more trip of 36 man days.

2.3.3 Two launch support trips were required to the NRR site in Brazil. The support required there for the BIME program was significant. Two complete receiving facilities, each including a Minitracker antenna system with associated TRADAT equipment for trajectory determination and uplink command capability were provided, and the total effort was 168 man days in the mission which included the launch of four rockets: A19.124-1 and -2, constructed at OSU, and A20.123-1 and -2, constructed at Northeastern University (NU) under an associated AFGL contract. A second trip of 56 man days of support was later required in support of the BEAM payload. Launch support again entailed an extensive array of ground support equipment, including the specially modified Minitracker II antenna with the new six-foot parabola.

2.3.4 One trip was made to the ARR facility in support of the MAP/WINE campaign. This project required one man for 77 days in preparation for and launch of the piggy-back sphere payloads aboard Norwegian Nike-Orion rockets, MM-1 and MM-2. In addition, this mission used Data Converter Boxes constructed by the Electronics Laboratory in support of a number of Dart Datasonde payloads; the Datasonde and some additional Dart inflatable sphere payloads were also modified in the field and required some additional support during the same time period.

2.3.5 One trip was made to the Esrange launch facility operated by the Swedish Space Corporation for the CAMP campaign. One man was supplied for 34 days in support of the Thermal and Atmospheric Dynamics (TAD) payload, using falling sphere AC-16 aboard a Nike-Orion payload. As in the case of the MAP/WINE campaign, a number of small met rockets were supported in conjunction with the launch of the major instrumented payload.

2.3.6 One trip involving one man for fourteen days was required to the Wallops Flight Center in Virginia for the TRACER support. Falling sphere AC-15 was successfully launched from A13.277 (NASA rocket designation: DR-66) during this project.

2.3.7 One trip was made to the Fort Churchill Research Range in Canada, and required 55 man days of support in conjunction with the launch of NASA rocket 27.045UE, which

carried an AFGL television camera aboard and used a wide-band carrier in the 2250 MHz band. Since the Churchill range does not include S-band receiving capability, the OSU Minitracker was used to track the vehicle in flight and provide magnetic tape recordings.

2.3.8 A two-man crew was supplied at the NOAA facility in Colorado for 47 man days for support of the CN^2 program. The OSU TRATEL antenna was used to track a total of fifteen thermosonde balloon payloads in this program.

2.3.9 One extended trip requiring sixty man days of support was required to the Chico, California, balloon launch facility. Although the primary purpose of this support was to provide data acquisition and recording (together with TRADAT derived trajectory information) for the BAMM II platform flight aboard balloon H82-11, two successful test flights of the experimental ranging through asynchronous PCM telemetry package (see section 4.3 of this report) were accomplished aboard balloons H82-08 and -09 during this same trip.

2.3.10 One trip requiring fifteen man days effort was made to the Holloman Air Force Base in New Mexico. This trip, made in support of the BAMM program, was to launch a test of the Stabilized High Altitude Research Platform (SHARP) before proceeding with the BAMM IIa program.

2.3.11 One additional trip on the BAMM II program was made to the Naval Air Station at Corpus Christi, Texas. This required 42 man days of effort in support of the launch mission.

2.3.12 A major support activity was required for the PIIE payload, A19.427, at the Sondrestromfiord launch site in Greenland. This project required two men for a total of 56 man days. Consoles for operation of the OSU-built payload components, as well as an OSU ground station for performance evaluation (operated in conjunction with the NASA receiving facility) were supplied. The desired conditions for launch of this payload were not achieved, and the launch was postponed. It will be rescheduled under the next following AFGL support contract.

2.4 Equipment Development Tests

No special trips were made solely to test new equipment developed at the Electronics Laboratory, but testing of such equipment was done in connection with other scheduled launch activities described above.

2.4.1 In connection with the BAMM balloon payload launch at Chico, both the experimental PCM ranging system and the PCM Command System which are discussed in

section 4.3 were tested during the flights of balloons H82-08 and H82-09.

2.4.2 The developmental Digital Az/El display and recording system described in section 6.3 of this report was tested at WSMR while conducting tests of error signal response of the airborne tracker in the TEM-3 payload under the MSMP project.

2.5 Miscellanous travel was also provided as support in two other trips during this contract.

2.5.1 One man was required for three days at the Tape Head Interface Committee (THIC) meeting in Laurel, Maryland. This was primarily to obtain information concerning High Density Digital Recording (HDDR) techniques and other applications of interest to development of improved PCM recording techniques under this contract. After attendance at the first meeting, all following data concerning activities of this group was obtained by mail.

2.5.2 One man was also supplied at the International Telemetry Conference in San Diego, California for three days. Leonard J. Skach presented a paper entitled "Minitracker, A Portable S-band Autotracker Antenna". Attendance at the other sessions of the conference also assisted in gathering data of interest in the overall work under this contract.

2.6 Coordination activities also continued through official visits by others to the Electronics Laboratory in Stillwater.

2.6.1 Contract manager J.R. Griffin/LCR visited the Laboratory on seven different occasions. Sixteen days were spent in meetings with the staff, reviewing both adminstrative and technical progress under this contract, as well as outlining new objectives to be pursued under our development program

2.6.2 Willard F. Thorn/LCR made two one day visits to our facility to discuss technical program plans in connection with ELC and CIRRIS projects.

2.6.3 Mr. Timothy J. Frank (ONR Resident Representative) visited the lab twice for the purpose of verifying compliance with contractual requirements for administrative procedures, reporting requirements, and equipment inventory records.

2.6.4 Mr. Michael J. Kennedy/LCR made one visit of five days duration to our Laboratory for purpose of completing tests and familiarization with TRADAT V electronic cards, which were assembled at AFGL in accord with OSU drawings.

2.6.5 Mr Edward F. McKenna/LCR visited the laboratory twice in order to review our position and discuss program plans in connection with resumption of activities after the

FY-83 "Stop-work" order. He was accompanied by Lt W. E. Day III/LCR, our new contract monitor, on the second occasion. A review of our plans for extension of the contract period through the end of FY-84 was also conducted.

2.6.6 Messrs. Juliano, Perez, and Davoli of the Instituto De Atividades Espaciais (Sao Jose dos Campos, Brazil) visited the Laboratory for two days, to view demonstrations and obtain familiarization with the Minitracker/Tradat V tracking and trajectory systems. Their visit was of potential interest in future applications at the NRR, Brazil, in connection with the Brazilian Equatorial Astronomical Measurements (BEAM) and High Altitude Recovery Program (HARP), both to be scheduled at the NRR in Brazil.

2.6.7. George E. Todd of DFVLR (GSOC) visited the Laboratory for two days to discuss results obtained from the Energy Budget Campaign (EBC) program and to review plans for the following CAMP and MAP/WINE projects.

3.0 MAJOR PROJECT SUPPORT WORK

One major item of service supplied under this contract has consisted of continuing support to major Upper Air Research projects. This support can be quite varied in nature and is dictated by the individual requirements of each project. It has normally included analysis of requirements, followed by development, design, and construction of the special electronic instrumentation to be required, either for airborne or ground support elements of the system proposed. Design and construction of custom PCM telemetry equipment is a typical form of this support, in which digital telemetry is developed to meet the specific needs and requirements of the mission. After building the prototype system and incorporating any desired modifications, construction and qualification testing of the flight equipment is done to insure that all requirements have been met. Delivery follows, and the equipment is next integrated with remaining elements of the system to verify mechanical and electrical compatibility of all items into the configuration desired. This is normally accompanied by further verification and calibration testing, including the desired environmental test conditions, prior to field deployment for the launch mission. Launch site activities include a rigorous system of pre-launch testing, followed by reception and analysis of the data during flight. In some cases, additional support may be required for post-flight data reduction and analysis, particularly if the mission has included trajectory determination. Some of the major support activities during this contract period have been long term in nature and represented a continuation and refinement of activities which were initiated under preceding contracts sponsored by AFGL. In the section which follows, these major support activities have been gathered together in rough chronological order and grouped in related projects for reporting purposes.

3.1 Multispectral Measurement Program Support Work.

This support has been a continuation of effort for a program which was initiated under AFGL contract F19628-75-C-0084 and continued through F19628-78-C-0033 until the beginning of the current contract. Within the current contract, our activities have been associated with both the TEM-3 and HPTEM projects; the TEM-3 project was completed and the HPTEM work discontinued late in 1983, prior to completion. Both projects have involved complex payloads requiring multilink telemetry systems and special PCM encoders which were developed here to meet the requirements of the large Aries class payloads. Each was designed to include a high-speed subsystem for the sensor link with high resolution PCM, including both digital and analog input data. Each also included an auxiliary PCM system which operated at a lower speed and with less resolution for the

associated target engine module, in which data was essentially housekeeping in nature. Both projects also involved some study and development effort for auxiliary equipment to be required in the mission.

3.1.1 TEM-3 Project Support Activities.

In accord with sponsoring Space Division policy, the TEM-3 payload was provided with two complete sets of components, each fully qualified under an elaborate program of testing, to insure that no compromise might occur in the complex field operation which was planned. Although the primary sensor system flown and recovered from the TEM-2 mission was modified and then requalified for TEM-3 use, a complete new duplicate system had to be built and qualified for use as the back-up set. The OSU portion of this payload included the primary sensor system telemetry encoder and the somewhat simpler PCM subsystem which was developed for the target engine module. In addition, although basic GSE items of general utility to the field operation already existed, special GSE was developed to facilitate testing of the on-board X-band tracker provided by the Cubic Corporation. Field operations included not only the actual launch support mission at the White Sands Missile Range in New Mexico, but also a number of trips to the Space Vector Corporation in California, during which simulated flight testing was conducted to verify operation of the ACS and instrument tracker on an air bearing table. The launch support mission also required additional services in calibrating the X-band tracker at the PSL range, prior to commencing the normal pre-launch testing at the launch site.

The sensor PCM telemetry coder was a revised version of the system originally developed by OSU under an earlier contract and has been described previously (Ref. 2, Section 4.1). The original system was later modified for use in the TEM-2 mission (Ref. 3, Section 4.1) and a second duplicate sensor telemetry system built and subjected to qualification testing. For use in the TEM-3 mission, the design was updated with improved grounding and shielding features added to reduce extraneous false bits in the serial data train; a new Analog-to-Digital Converter was installed to improve coding accuracy and a six-pole premodulation filter added within the encoder. The final version operated at 400 Kilobits per second, in Non-return to Zero-Space (NRZ-S) code format to minimize loss of synchronization when long continuous strings of zeroes appeared in the instrument data. Twenty-eight words of 14-bit length were used per minor frame, and subcommutation provided through use of a major frame one hundred minor frames in length. A mixture of digital and analog data was accommodated; digital data was inserted in the first four data words (and in the first portion of subcommutated housekeeping data in word five); analog data inputs were converted to 12-bit accuracy

and two zero bits of fill added throughout the remainder of the frame. Word zero was a normal Barker code frame synchronizing word and sub-frame identification (SFID) supplied in binary form in the last seven bits of word one, following a fixed seven-bit code. Digital pixel data 14 bits in length was accommodated in words 2 and 3 (and was also available in spare word 4). Words 5, 7, 19, 20, and 21 were allocated for 100-word long subcommutated housekeeping data strings, some of which were provided with supersubcommutated sampling rates. Words 6 and 14 through 18 were conventional analog input main frame words, while words 8 through 13 were double-sampled by being repeated again in words 22 through 27 as supercommutated data inputs. Outputs included both adjustable premodulation filtered signals for the associated Link 1 telemetry transmitter and a line driver output for testing by a hard-line coaxial cable from a separate connector. Documentation of the design has been provided through the OSU X39MXXX drawing sequence. The relatively elaborate qualification testing required for this mission was performed under microcomputer control, using the technique developed under this contract and described briefly in section 5.4 of this report. (A more complete description of this testing procedure will be found in Scientific Report No. 1 to this contract, Ref. 10.)

The target engine module of this complex payload was provided with a completely independent PCM telemetry subsystem, also designed and constructed by OSU. This was originally developed as a replacement for an earlier analog telemetry system, and designed to fit the same mounting details. A remote multiplexer was provided as one element of this telemetry subsystem, replacing an earlier analog commutator, to permit sampling a number of temperature sensors in the aft portion of the payload and provide the mixed analog data (synchronized with the basic PCM encoder) as input to the internal A-to-D converter for use as one subcommutated word. The system developed has been described previously in conjunction with TEM-2 support activities under the previous AFGL contract (Ref 3, section 4.1.2). This PCM subsystem operated at 190 Kilobits per second, again in NRZ-S code. The format consisted of twelve words of 8-bit length per minor frame, and used 40 minor frames per major frame to provide subcommutation capability. Word zero was Barker code frame synchronization; word one provided binary-coded SFID. Eight of the available data words were subcommutated: one presented the forty temperature sensors from the remote multiplexer, while the remaining seven used super-subcommutation technique, repeating eight inputs five times per major frame. The basic PCM coder again provided a "hard-line" monitor output for use in testing, and also provided synchronizing signals at major and minor frame rates as timing for the remote multiplexer. Qualification testing on both the flight and back-up models of this

subsystem was again done through the automated test procedure under microcomputer control, as described for the sensor encoder (see Ref. 10). Documentation of the design is provided in th OSU X39TXXX series of drawings.

Auxiliary equipment developed and built for use on this project included two special items, both designed and built to facilitate tests and calibration of the associated X-band tracker within the main payload. (This tracker, mounted in the sensor portion, was meant to track the target engine module after separation). Elevation and azimuth axes of the testing platform were provided with angle resolver outputs, converted to 3-digit BCD angular error signals by an available Scientific/Atlanta Synchro-to-Digital Resolver. One auxiliary GSE device was provided to encode, in serial PCM form, this Azimuth and Elevation readout data. This permitted recording the data, together with associated AGC error signal data, on magnetic tape during calibration of the system. The second device was provided to permit display of the angle error data on strip charts in analog form, working either from the real time or tape playback signals, to analyze the calibration results. (Both of these GSE devices are described in section 6.3 of this report.)

Field support services provided in connection with the TEM-3 project were relatively extensive. Four separate trips were made to the SVC facility in Northridge, California before deployment of personnel and equipment to the launch site, and one additional trip was required to the WSMR facility before successful launch of the payload was accomplished. The trips to SVC required a total of 21 man days of effort, and included an extensive series of tests on the Attitude Control System (ACS) which SVC supplied for this payload. These tests involved the use of much of the same GSE which OSU was to supply later at the launch site, in order that air bearing tests might be made and evaluated in the same manner proposed for flight while testing performance of the ACS system under simulated flight conditions. Some of the special GSE devices provided for this testing program are described in greater detail in section 6.3 of this report, including the special PCM system supplied to SVC for monitor of the air bearing test. During this testing program, a "fly-by" test for the on-board X-band tracker was also performed while the payload was mounted on the air bearing table. Shock and vibration testing was also performed, and the system then subjected to post-shake testing to verify that the payload was ready for shipment to the launch site and assembly for pre-launch testing. Field support at the New Mexico launch site required an additional 45 man days of effort, and a typically complex array of GSE from the OSU laboratory which was integrated into the existing WSMR support station in such a way as to permit quick evaluation of the

desired performance of all elements of this extremely complicated payload. Several days were required for calibration of the X-band tracker, during which this active portion of the payload was taken to the PSL antenna range and mounted on their test platform, to examine the accuracy with which the Cubic equipment in the main payload could track the X-band source within the target engine module. For these tests, the Az/El encoder and Az/El DAC readout display units described above were used; this successfully verified both the performance of the payload and the suitability of the special GSE for its intended use. The payload and all GSE was then moved to the WSMR site for prelaunch testing, which required both clean-room assembly and tests and later vehicle/payload assembly on the launcher, with normal horizontal and vertical tests performed before the actual launch countdown occurred. During these tests, an intermittent problem was found in the telemetry monitors from the X-band tracker when assembled in flight configuration. This caused a two-day delay in the schedule, during which the spare back-up tracker was installed in the flight payload. Successful prelaunch checks were followed by launch of rocket A24.609-3, carrying the TEM-3 payload, at 0947 local time on 28 May 1982. A good flight ensued, with apogee at approximately 147 miles. One instrument door did not close properly at re-entry, which partially compromised recovery, but resulted in little damage to the payload. Data achieved, with the exception of that from the HS-4 instrument, was excellent.

3.1.2 HPTEM Project Support Work.

After successful launch of the third payload in the TEM program, plans began for a shift in the MSMP program to the following phase, flight of the follow-on high performance version of the same experiment over a much longer flight path. A planning meeting at AFGL was first held to review and define the requirements for this mission. In addition to definition of the telemetry requirements, which permitted redesign of the PCM telemetry systems to be used, two new problem areas requiring study emerged: because the anticipated flight profile was such as to permit substantial physical separation of the target engine module with respect to the sensor module, some system of determining the separation distance was desired, and the possibility of adequate receiving antenna beamwidth for tracking and acquiring telemetry data from both modules at the same ground site appeared difficult. Two study programs were immediately begun under this contract: one was development of an airborne intervehicle ranging system for addition to the payload, while a second study was to investigate the use of a data relay system for telemetry from the target engine module, via the sensor module back to the ground receiving site.

The intervehicle ranging study is reported in greater detail as follows. In brief, the first approach was to consider use of two available C-band airborne beacons for this measurement. One was modified so as to permit interrogation to be synchronized with the frame rate signal from the PCM telemetry system, and retuned so as to operate with the normal interrogate/reply frequencies inverted. This beacon, within the sensor module, then served as a rudimentary airborne radar. The second beacon, installed within the target engine module, was to operate as a normal transponder. Within the sensor module, an onboard time interval counter was started by the outbound interrogation pulse, in synchronization with the telemetry frame sync pulse. The reply pulse (from the second transponder in the target engine module) was then taken from the receiver output of the interrogating beacon within the sensor module and used as the stop pulse to the interval counter. The output of the time interval counter, proportional to the range between the two modules in flight, could then be corrected for system delay, converted to BCD form, and inserted as data within words of the PCM telemetry string from sensor module to the ground receiving station, thus providing the intervehicle range in digital form. Because the anticipated maximum useful range of this system was only estimated as 40 Km, and later analysis indicated spacing might be as much as 90 Km, the study was next shifted to a second similar approach. Concurrent work on development of a form of the TRADAT system suitable for use with PCM telemetry downlink data (see section 4.3 of this report) had led to development and test of a modified airborne package which had similar characteristics, but used the normal lower frequency ranging transmitter (with consequently greater range due to reduced path attenuation) and the standard form of ranging receiver aboard the target. For this version, the telemetry frame sync was used to develop the coded "uplink" signal from sensor to TEM; the output from the TEM ranging receiver was then conditioned and returned to the sensor module via a second carrier frequency. The coded outbound signal and received reply then could be used as start and stop signals to the interval counter and, as before, converted to BCD form and inserted within the sensor PCM data string to provide the intervehicle range desired.

The second study is described in section 5.5 of this report. It was proposed that the S-band telemetry link aboard the target engine module be retained as planned. For the early portion of the flight and for portions of the path in which the receiving antenna beamwidth covered both elements of the payload, this signal could be received directly through the ground multicoupler and a suitable receiver. For regions within the flight path where the ground-based antenna could not acquire data from both modules because the intervehicle spacing exceeded the beamwidth limitation, an S-band receiver aboard

the sensor module could be used to receive the TEM telemetry by a simple antenna system on the gimbal-mounted portion of the payload, which was automatically pointed toward the target engine module. This signal, after reception and signal conditioning, could then be used as PCM data for a fourth S-band link aboard the sensor module, fed through a quadraplexer to the normal sensor module antenna. This relayed signal then was available at the ground-based antenna tracking the sensor module. The studies showed that both systems were feasible solutions to the anticipated problems, but both requirements were subsequently deleted from the plans for the HPTEM mission.

Two separate PCM telemetry coders were developed for the HPTEM mission, one each for the sensor and target engine modules. Both were derivations from the earlier telemetry systems of the TEM program, based upon the required changes to satisfy the needs of the HPTEM program. Format for the sensor module PCM system was set after discussion of the anticipated requirements, which included a 1000 per second sampling rate on prime data and a mixture of digital and analog input data to the system. The proposed system was to operate at 280 Kilobits per second in NRZ-S coding, with 14-bit resolution required for total of twenty words per minor frame. Requirements for lower speed sampling were met by providing subcommutation with a major frame length of 100 minor frames. Word zero was allocated for the standard 14-bit Barker code frame synchronization signal, and word one provided a fixed 7-bit fill pattern, followed by SFID in 7-bit binary form. Digital data was clocked in from the instrument for word two and the first few frames of subcommutated word three, after which a transfer was made to the multiplexed analog information input for conversion to digital data. Both the conventional adjustable amplitude signal for modulation of the associated S-band transmitter and a hard-line fixed amplitude PCM monitor for umbilical use were available from the unit, which also included a six-pole premodulation filter and DC/DC converter to provide all necessary operating voltages from the available 28 volt DC battery power. The OSU drawing series X42HSXX was allocated to document this design, and a set of drawings was started, but the project was placed on a "Stop-Work" basis before the full set had been completed. After construction of the breadboard prototype version of this coder and testing to insure agreement with specifications, construction of two subsystems was begun.

A second PCM system was developed for the TEM telemetry link. Again, previous experience gained in the TEM-3 flight was utilized to permit rapid development and fabrication of a suitable system. The combination of accuracy requirements, desired sampling rates, and number of inputs required dictated the design. A bit rate of 224

Kilobits per second was used, with fourteen words of eight bits to each minor frame, and output in the NRZ-S configuration. Subcommutation capability was provided though use of a forty frame long major frame. As in the case of the sensor telemetry system, both transmitter modulation and hard-wired line-driver outputs were provided, with a six-pole premodulation filter and internal DC/DC converter power supply. Word zero was Barker code frame sync and word one assigned for a 6-bit binary SFID, preceded by two coded fill bits. Forty separate temperature sensors were again remotely located in the aft portion of the overall payload, and so an auxiliary remote multiplexer was included as a portion of the subsystem. This remote multiplexer was again operated in synchronism with the main PCM coder, but differed from that previously supplied for the TEM-3 system by using six parallel address lines from the main system frame counter to drive the multiplexer, in place of using internal counters synchronized with minor and major frame sync signals. Words zero and one were again frame synch and SFID, with word two assigned for the data from the remote multiplexer (40 temperature sensors in the aft portion). Words three through eight were supersubcommutated; each presented eight input signals in sequence, repeated five times per major frame. The remaining four words were available for high-speed (2000/sec) data words. The X42HEXX drawing sequence depicts electrical and mechanical details of the main target engine coder, while the X42HRXX sequence shows corresponding details for the remote multiplexer. Both of these drawing sequences were completed.

Two complete TEM subsystems, including remote multiplexers, were built in flight configuration and qualification testing was completed, using the automated test program developed for the TEM-3 system with minor modifications to the software in order to adapt it to the HPTEM requirements. Two complete sensor telemetry subsystems were started, but only the mechanical shop work was completed and the electrical wiring was underway, together with the necessary drawings for documentation, when the HPTEM project was placed on a "Stop-work" order in late 1983. It appears unlikely that this project will be resumed, but it is possible that a related program may be undertaken in the contract to follow, so all items remaining (including components purchased for the HPTEM project) are being held in storage at OSU.

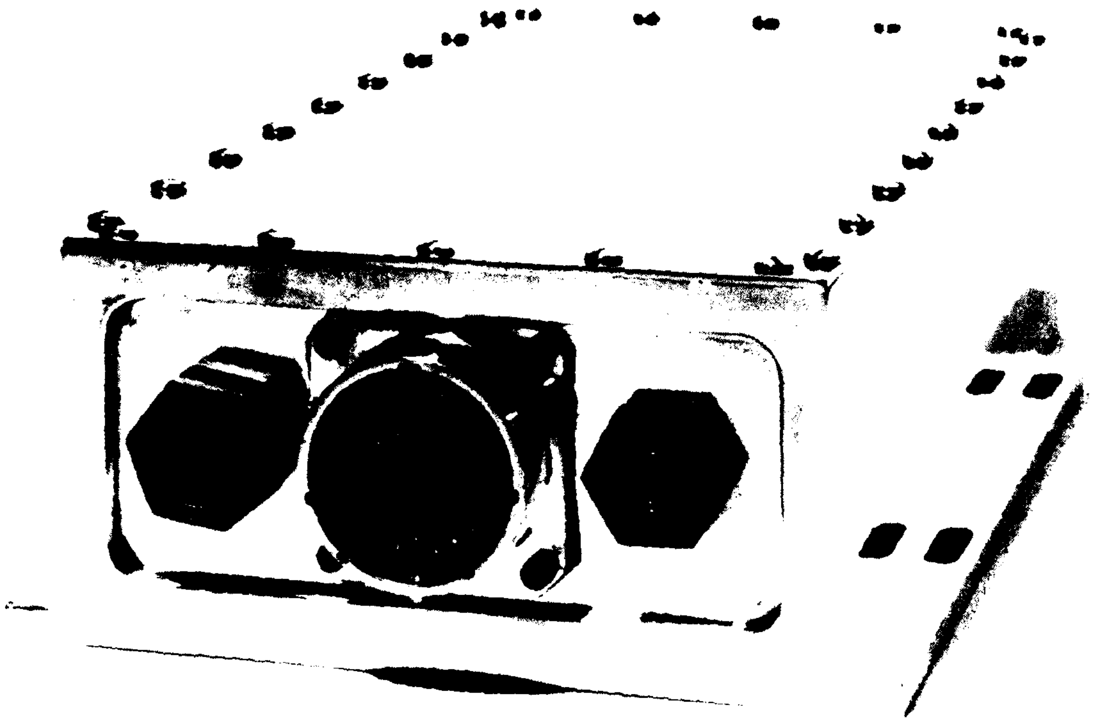
3.2 Background Measurement Program Work.

The overall BMP projects pursued within this contract period embraced a number of related projects, many of which were again continuations of work initiated under previous AFGL contracts and continued into the current contract. Other projects arose in the course of this contract; some await completion and so will be continued under the

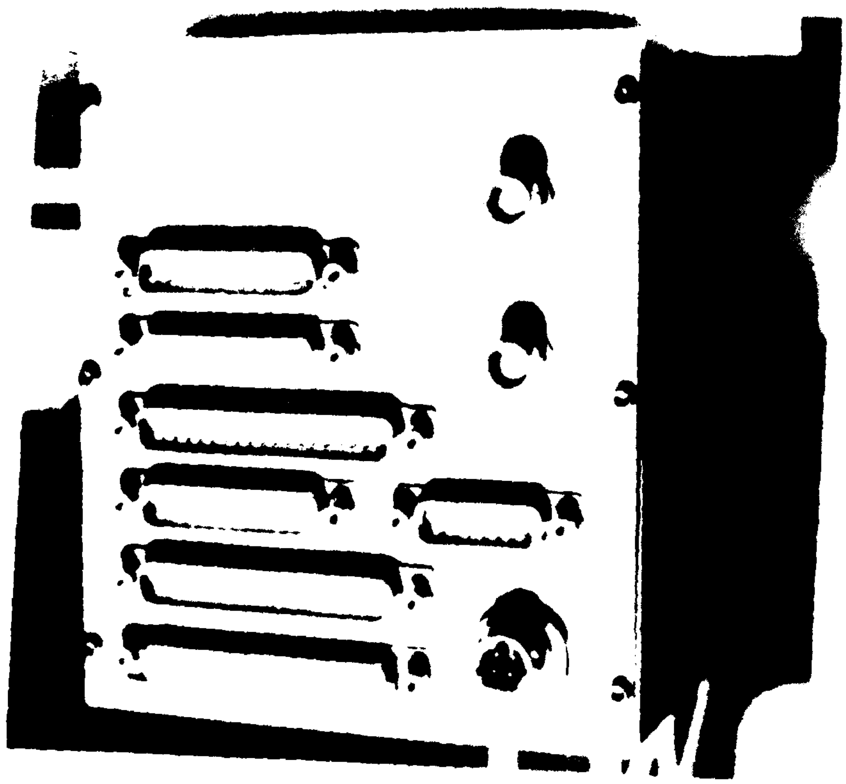
next following contract in this sequence. Because these projects were all performed under Space Division sponsorship, each required that two complete sets of airborne components be constructed and qualified, in order that a fully qualified back-up system be available in the field during each launch mission. As described previously, the qualification testing was quite extensive and performed under automatic computer control. (See reference 10 for a complete description of this method of testing, including the software which was used for most of the subsystem tests.) Since each of the payloads in this series of projects was large and complex, the field support requirements were very similar to those described for the MSMP work and included both a multiplicity of trips and deployment of an elaborate assemblage of GSE in order to provide the necessary capability for evaluation of the performance, both to verify flight readiness and for actual flight data interpretation.

3.2.1 Zodiacal Infrared Project Support Work.

Support for the ZIP-2 mission was one of the projects continued from preceding contract F19628-78-C-0033. The ZIP-1 payload, PCM telemetry components, and launch activities, together with preliminary work toward the preparation for the ZIP-2 project, have been reported earlier (Ref. 3, sections 2.3.1 and 4.3.2). The PCM telemetry subsystem provided by OSU was complex, requiring two relatively high speed links which operated in synchronism with some degee of redundancy in both data word assignments and timing features. Physically, the subsystem included an on-gimbal module which included two separate data multiplexers and A-to-D converters (one to feed each link of the two link system, each receiving timing signals and input data from separate sources), plus two separate but related off-gimbal units (one for each link). Each of the two links operated in NRZ-S code at 616 Kilobits per second; they were driven from the same clock oscillator and used similar timing circuits, but had redundant circuits to generate different frame sync patterns and separate 6-bit fill patterns preceding the SFID data, which was in 2-digit BCD form at the end of word one. Each link was formatted for a minor frame of 44 words of 14-bit length and had subcommutation provided by a major frame 88 minor frames long. Digital data was accommodated in words two through five, and analog input data was converted to digital form by A-to-D converters for the remainder of the frame in each link. Words 2 through 11 were operated in parallel for both links, providing redundancy in both the digital data and the common housekeeping data of analog form, which included two subcommutated words. (Analog housekeeping data in this common format was only converted to 12-bit resolution, and had two bits of zero fill added.) The primary instrument had 32 separate sensors, each provided with two



On Gimbal



Off Gimbal

Figure 1 ZIP-2 PCM Encoder Components

(high and low gain) outputs. For the remaining 32 words on each link, sensor outputs were so divided as to put low gain and high gain signals from each detector alternately in link 1 and link 2 assignments, in such a way as to preserve the high gain output from one half of the sensors and the low gain output from the other half, in the event that one of the telemetry links should fail in flight. Prime data words were converted to the full 14-bit accuracy possible from the A-to-D converters for this latter data assignment. The coder for each link included both adjustable transmitter modulation outputs and separate fixed line-driver signals, for use in hard-line checks from the payload during the test phase. The basic design of this dual PCM link system has been previously documented as the OSU X39ZEXX drawing series for the off-gimbal units and the X39ZGXX series for the on-gimbal system. The system components (for one channel only) are shown in the photographs of Figure 1. Both the recovered version from ZIP-1 and a new back-up spare unit were updated with the improved grounding and lower noise features for better resolution of the prime instrument data, then subjected to full qualification testing through use of the automated check procedure described in reference 10.

Following the calibration and preliminary testing at AFGL, which required no participation from OSU in preparation for this mission, the launch support mission began at the White Sands Missile Range. Two men were required for this purpose, and the PCM ground station was more elaborate than usual because of the large number of PCM signals to be decoded from both the main two-link dual PCM system described above, plus the associated link 3 Boost Control System telemetry, which used a PCM encoder procured elsewhere. In order to display the requisite number of decoded words, the newly developed OSU DAC-20 microprocessor-controlled PCM decoder (see section 6.1 of this report and Scientific Report No. 3 to this contract, Ref. 11) was added to the normal pair of OSU PCM decoders, together with two OSU Model C90DB01A 8-Channel outboard DAC systems (Ref. 3, section 8.2.1) and the Model B39MG01 16-Channel Bar Graph Display (Ref. 3, section 8.2.3). (These special GSE items were developed under preceding AFGL contract F19628-75-C-0033 for use with the complex BMP payloads, and were designed to operate as auxiliary equipment which were driven by and expanded the capability of either the standard OSU Model D90RF01 Single-Channel or D90RP20A Five-Channel PCM decoders.) A first trip to WSMR in June of 1981 required 26 man days. The prelaunch tests disclosed problems in the Star Tracker system, followed by an unexplained failure in the link 3 Boost Control System telemetry. The launch mission was consequently postponed to permit replacement of the questionable components. The same two men returned the following month for an additional 30 man days of support, during which the prelaunch and assembly procedure proceeded smoothly. Following the

normal sequence of clean-room assembly and launch pad checks, the payload was successfully launched aboard rocket A24.6S1-2 at 0452 MDT on 31 July 1981. An apogee of approximately 245 miles was achieved, with good scientific data and successful recovery of the payload section later the same day. Following recovery, the PCM subsystem was removed and laboratory tests made to investigate the possibility of modifying the entire system to operate at a higher bit rate of approximately 1 MHz, in anticipation of even higher data sampling rates at the same 14-bit resolution for future missions. With some care in controlling stray capacities and phase adjustments in the timing pulses, this operation proved possible.

3.2.2 Far Infrared Spectral Survey Experiment Support Work.

Services for the FIRSSE mission also began under preceding contract F19628-78-C-0033 with the design of a special two-link synchronized PCM encoder. The first flight version of this airborne equipment had been constructed and was ready for qualification testing at the time services were started under this contract (Ref. 2, section 4.3.3), and a second back-up system was to be constructed under the normal Space Division requirements. The coder design was documented in the preceding final report (Ref. 2, section 4.3.3), and was a relatively complex PCM subsystem. The required sample rate for the array of 71 sensors was 1600 per second (fifteen of these were to be doubled to 3200 per second), with 12-bit resolution. In addition, digital data generated within the payload was to be inserted, and other housekeeping requirements added many words with varied but lower sample rate requirements which could be accommodated within a subcommutated format. Even with a synchronized two-link data transmission system, these requirements pushed the minimum acceptable bit rate to 960 Kbps, and NRZ-S format was dictated by the nature of the sensor outputs, primarily bipolar signals with a span of ±10 volts and zero output at no signal conditions. The final format chosen used fifty words of 12-bit length per minor frame, with subcommutation provided by the selection of a major frame which was 64 frames in length. Documentation of the design is available in the OSU X39FXXX series of drawings. As usual, all digital data was inserted first, with a transfer to analog input data occurring at the beginning of word 3 for both links. Word zero was frame sync for both links; link one used the normal 12-bit Barker code, while link two used the first 12 bits of the normal 13-bit Barker code. Word one contained SFID, but was somewhat unusual in format: a fixed 5-bit fill pattern for each link was followed by the 6-bit binary SFID data, and the last bit of this word was actually the most significant bit of the 13-bit digital input data from the shaft encoder which indicated gimbal position. This shaft encoder data was transmitted in word two of both links, providing

redundancy in information in the event one link should fail in flight. (Sensor outputs were also assigned in such a manner as to permit recovery of at least half the data from each group of sensors if one link should fail by dividing sensor data assignments between the two separate links; the fifteen sensors for which double-rate sampling was desired were all sampled early in the minor frame of link one and the second sample was made one half frame later in the synchronized data from link two.) Subcommutated housekeeping data was inserted immediately following the switch to analog input data after word two. Link one had two subcommutated words as 3 and 4, each sampled at the required 50 per second rate by supersubcommutating a group of 32 inputs, repeated twice in each frame. Link two used a more elaborate subcommutation scheme, requiring the assignment of words 3 through 6 for this purpose, each with a different sample rate. Word 3, at 25 per second, utilized 64 inputs. Word 4 sampled 16 inputs at 100 per second by repeating the sequence four times in each major frame. Word 5 provided seven monitors at 200 per second by supersubcommutating these inputs eight times per major frame, and provided eight additional monitors at 25 samples per second. Word 6 provided 32 monitors at 50 per second in the same manner used for link one. Physically, the system used an on-gimbal box which contained two A-to-D converters, one for each link, with timing provided from the off-gimbal system, which included two additional A-to-D converters. The outputs for each link, from the off-gimbal system, included both a standard line-driver for hard-line tests, and an adjustable transmitter modulation output, taken through a pre-modulation filter.

A duplicate system was constructed as a back-up for flight, and both systems were run through the elaborate qualification test procedure under the automated test routine by using special software developed for the FIRSSE project, as described in Reference 10.

Integration testing required the services of one man for six days and was performed at the Ball Aerospace Corporation facilities in Boulder, Colorado in mid-1981. Later, during payload calibration activities at the AFGL facility in Massachusetts, problems were encountered in digital data which appeared related to noise and offset voltages, and the services of one man were required for a week there in isolating the problem, then correcting it through modification of the grounding system and cabling shields. These calibration activities also included the first operational use of the microcomputer-controlled DAC-20 system which was developed under this contract and, although not yet in final form, was available for use in sorting words from the complex PCM format (Ref. 6.1.1 of this report); some training and familiarization with the capabilites of this GSE item was provided to AFGL personnel in connection with this same trip.

Prelaunch field activities began at the WSMR site in New Mexico in late 1981 and required several individuals at various times, with a total expenditure of effort of 67 man days. The complexity of the payload again required elaborate GSE systems similar to those described previously for use in the BMP support program, and was interrupted in December by the holiday shut-down at the range. The crew returned in early 1982 and, after a three-day delay in schedule to resolve some problems in the infra-red instrument section, proceeded through the dress rehearsal and launch phase aboard Aries vehicle A24.7S2-2, with lift-off at 0800 UT on 23 January 1982. Vehicle performance was excellent, with an apogee of approximately 378 Km, roughly five percent higher than anticipated. Good scientific data was achieved, supporting systems functioned as planned, and successful recovery was accomplished.

3.2.3 Earth Limb Clutter Project Support Work.

Support for the ELC-1 payload originated within this contract. This project, also using a multi-channel infrared sensor array, was an outgrowth of the ZIP work reported previously in section 3.2.1 of this report. The PCM subsystem for this project was based upon the ZIP design, since requirements were similar in nature and the previous concept had been proven through flight on two missions. The initial requirements appeared to be roughly identical, with the exception of minor reassignments of data lines within the format and a higher sample rate requirement of 1700 per second, which was to be met by an increase to 1.0472 Mbps in the 14-bit per word NRZ-S format of 44 words, with a major frame lentgh of 88 frames for subcommutation. The change to a higher bit rate revealed some timing problems in the coder design, which required some corrections for the delay introduced by cabling between the components of the subsystem and led to elimination of the earlier redundant clock system for links one and two, with cross synchronization capability. The basic general design of a single two-link on-gimbal installation and separate off-gimbal boxes for each link was retained, but all timing for both links was provided from the clock within the link one off-gimbal box. The improved versions of cabling and shielding which had been developed for the FIRSSE encoder were also incorporated in building the ELC-1 systems, but the features for many portions of the system remained those documented in the X39ZXXX ZIP drawing sequence; changes were documented by new drawings in the X42EEXX series where necessary. Two PCM systems were supplied as the flight and back-up spare systems, and full qualification testing was accomplished on both through use of the automated test procedure, but a number of modifications to the KIM system were required before the high-speed, high-resolution PCM system could be satisfactorily tested to the desired conditions. New and

revised software was developed for this encoder, and a number of hardware modifications were also made to the system (including the addition of optical couplers and revised grounding, to reduce the effect of extraneous noise on the coding which could be achieved with the specially selected 14-bit A-to-D converters). The general procedures used for testing have been described (Ref. 10 and 5.5.2 of this report), and details of the special changes are presented in section 5.5.1 of this report. Tests of the first subsystems were delayed while the test system was revised, and the items delivered to AFGL. Subsequent calibration activities there disclosed a defective A-to-D converter, so the unit was returned for replacement and repeat qualification tests.

During this period it was found that the Inertial Reference Unit (IRU) of the associated attitude control system being supplied by the Space Vector Corporation for use in this payload was to impose additional requirements upon the PCM subsystem. The monitors for the IRU were digital in nature, and used a special low speed format so that the data could be recorded on a conventional audio cassette recorder; this required that a relatively low bit rate NRZ-L signal be used with the cassette recorder. (The digital IRU monitor was in the form of 8-bit subwords and used a total frame length of 165 bits; actual sync and data words were assigned as multiples of two, three, or four 8-bit subwords, with "fill" bits in a blank last word to adjust the frame length.) To accommodate this requirement in the telemetry format, an unusual technique was developed. The basic bit rate for the downlink PCM was adjusted to 1.0164 Mbps and a timing signal fed to SVC, for countdown and use as the low bit rate for the internally generated IRU monitor. This provided a minor frame rate of 1650 per second for the downlink signal in the PCM, and SVC could then count the clock signal down to derive a ten per second data rate for the IRU monitor by using a monitor bit rate of 1650 per second for the 165 bit long frame, keeping their monitor synchronized with the telemetry frame rate. The IRU NRZ-L digital monitor then became a series of "high" or "low" signals of one PCM frame in time duration, each representing a single bit of the IRU monitor. Word seven in both links one and two of the ELC telemetry system were assigned for this monitor. With the signal so assigned, the A-to-D converter within the off-gimbal units of the PCM telemetry subsystem converted the IRU signal to either of two arbitrary "high" or "low" codes, representing the ones and zeros of the NRZ-L monitor in a rather unconventional form of subcommutation. Each frame of the downlink signal transmitted one bit of the monitor; the fact that the monitor contained an internal frame sync code eliminated the requirement of maintaining any relationship of this coded monitor signal with the major frame length of 88 frames, nor was the SFID word required for SVC use. Word seven in either link could now be selected in the GSE PCM decoder,

converted back to a string of ones and zeros by the DAC within the decoder, fed through an external bit synchronizer operating at 1650 bits per second for conversion to Bi-Phase Level coding, and recorded directly on the SVC cassette recorder. This system permitted either real-time or tape playback modes of operation from the ELC payload.

The choice of this system of monitor for the IRU within the ACS provided by SVC led to still another service: provision of a suitable telemetry system for use at their facility when conducting the necessary air bearing tests on the ELC payload. A special low frequency PCM encoder was developed, constructed, and supplied to them for this purpose, with the system so designed as to permit the existing model C90FT01 encoder at [illegible] be replaced by the new version (as shown in the OSU drawing C42EA01), while [illegible] transmitter to relay data from the air bearing table to the terminal [illegible] Cambridge site for the tests. The parameters chosen for this new [illegible] were such as to provide the necessary transmission of the IRU [illegible] under test and still provide capability for transmitting all other [illegible] and recording of the table-mounted equipment under test. [illegible] faster rate of about 1652 per second in this auxiliary system [illegible] from the IRU monitor stream would be missed in transmission.) The [illegible] telemetry system was installed and the feasibility of the IRU digital [illegible] demonstrated during a trip to the SVC facility in California, which [illegible] period of four days.

Following tests and calibration activities, modifications to the system to be flown imposed new requirements on the PCM encoder by a change in format in which the earlier digital data assigned for use in words three and four was to be replaced with analog data. This change necessitated returning both models of the encoder to OSU for wiring changes, switching both internal wiring for the digital/analog multiplex switch and input connector wiring. After making the required modifications, both encoder subsystems were run through complete qualification testing again to verify flight readiness before redelivery to AFGL and final testing for shipment to the launch site.

The final launch support at the WSMR facility required two men for a period of 37 man days in the fall of 1983. An elaborate system of GSE was provided to enable proper evaluation of equipment performance, including both the normal OSU five-channel PCM decoders, the three available outboard DAC units for an additional 32 words of display on strip-chart recorders, the 16-channel bar graph display system, and the DAC-20. Checks disclosed some noise problems in the ACS system, which were eventually resolved. After a successful dress rehearsal, the launch countdown proceeded and the payload was

successfully launched aboard Aries A24.260 at 1146 UT on 25 October 1983. Performance of the vehicle was nominal, the desired data was achieved in flight, and successful recovery accomplished later the same day.

3.2.4 Survey Probe Infrared Celestial Experiment Support Work.

Several different areas of work were involved in support services supplied under the SPICE project. Following evaluation of the mission requirements, a custom PCM telemetry subsystem was developed to meet the flight specifications. Two of these subsystems were constructed in flight configuration and submitted to the usual Space Division qualification test procedures prior to delivery and normal launch support at the WSMR. Concurrent with development of this airborne PCM system, the design of a special digital word-sorter and selection of peripheral equipment for a special ground terminal was also undertaken in order to provide a digital system with the capability of operating in real time, sorting and storing up to 64 words selected from the incoming high bit rate serial stream, then interfacing with a computer for conversion of the digital data to the desired engineering form of data, with output via both a digital plotter and a digital printer for convenient interpretation of data.

The special PCM encoder developed for this application differed substantially from the units described previously. Three IM6654AIJG EPROM chips internal to the wire-wrap cards provided a flexible and compact system for control of the format used in the telemetry system; changes in the format could be accomplished by simple changes in the programmed memory map for each EPROM. An Intersil Model 6920-CEP programmer under computer terminal control was used for initial programming of the EPROM chips. Later the OSU KIM-4 microcomputer system was modified to provide special software and hardware changes (See section 5.5.1 of this report) which will now permit its use to program the EPROM chips. The required resolution of data from the complex array of IR sensors in this payload at a sample rate of 1600 per second required raising the bit rate to 1.25 Mbps in a single link system, using NRZ-M coding and 65 words per minor frame. Housekeeping data with lower sampling rate requirements were provided by a number of subcommutated words within the 64 frame length of each major frame. Word zero had the conventional 12-bit Barker code frame synchronizing signal, while word one provided five fixed bits of fill, followed by a conventional 6-bit binary SFID code. Since no parity bit was required in this word, the last bit of word one was assigned for transmission of the first bit of the 13-bit long Gray-coded shaft encoder digital data; the remaining 12 bits of this shaft encoder data word were then presented as word two. At the beginning of word three a shift was made to analog input data and the A-to-D converters (one on-

gimbal and a second off-gimbal) were used to encode the analog data to 11-bit accuracy for the remainder of the frame. A parity generator in the off-gimbal unit provided an odd parity bit as the twelfth bit of all remaining words. Words three through eight were assigned for subcommutated data; word three was supersubcommutated, repeating a sequence of sixteen monitors of the ACS/BCS performance four times per major frame for a rate of 100 per second. Word four also provided eight additional ACS/BCS monitors, repeated eight times per major frame to yield the 200 per second rate requested, and also included eight housekeeping monitors at the standard 25 per second rate. Word five was assigned for Wentworth Institute housekeeping and provided 64 monitors at a rate of 25 per second. Word six was more complex, mixing three performance monitors supercommed eight times (for 200 per second sampling of a three-axis accelerometer) with seven position monitors which were repeated four times to yield 100 per second sampling. Two double-sampled monitors (50 per second) and the remaining eight inputs were also available at the lower 25 per second rate within this word. Word seven carried another complex subcommutated set of monitors from the sensor system: eight were sampled four times per major frame to provide 100 per second data, and sixteen others were double sampled to yield 50 per second monitors. (Frames 7 and 8 of this word consisted of eleven flag bits each, followed by the parity bit, and were all transmitted at the 4-times repeat rate of 100 per second.) Word eight was allocated for sensor on-gimbal monitors and repeated 32 of these inputs twice per major frame. Words nine and ten were respectively assigned to the Star Mapper signal and a high resolution potentiometer (for a sensor position monitor); the remaining inputs were all used by the array of prime sensors on the gimbal-mounted instrument. Details of the system are documented in OSU drawing D42SE01, which combines the on-gimbal and off-gimbal portions in a single schematic drawing. The off-gimbal unit is shown in Figure 2 on the following page, and provided both the adjustable pre-modulation filtered signal to the associated link one transmitter and a line-driver output signal for use as a hard-line monitor from the system. The on-gimbal box resembled the ZIP version and was also built in a polished one-piece box to facilitate clean-room assembly procedures. Two complete subsystems were constructed and qualified to mission specifications before delivery to AFGL.

Two men were supplied for 26 man days of effort in preliminary testing at the WSMR site in July of 1982. A number of problems in the GSE complex caused minor delays in the countdown procedure prior to the dress rehearsal countdown, primarily due to the high bit rate of this system, which made timing critical for much of the complex and required some field modifications and chip changes before satisfactory operation was achieved.

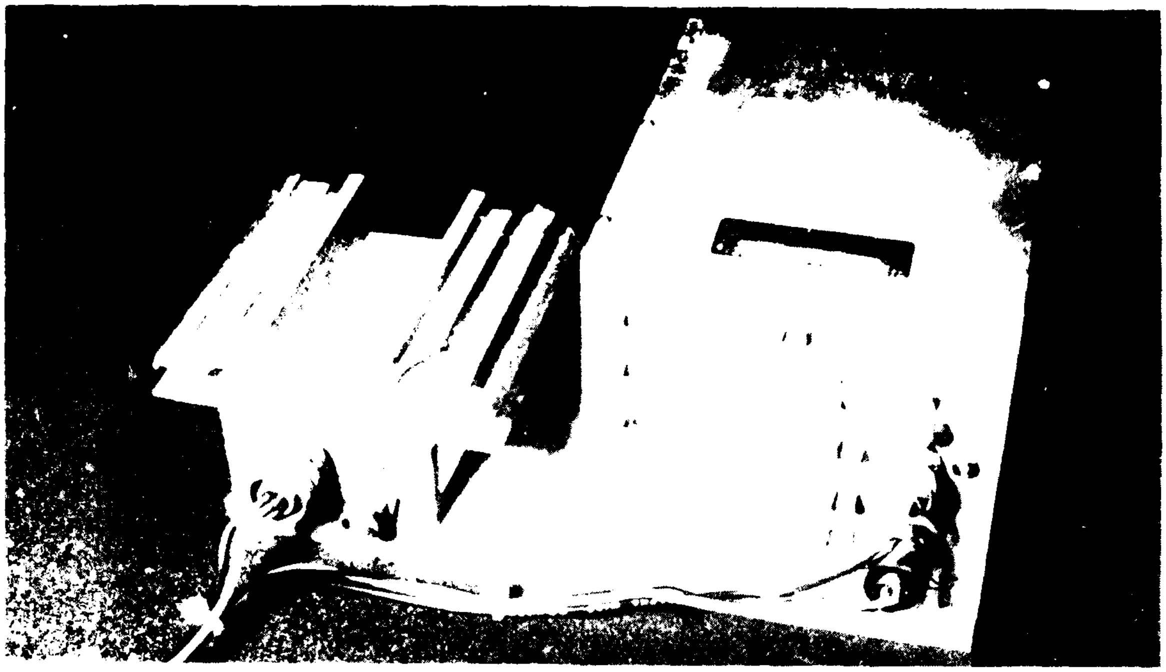


Figure 2 SPICE-2 PCM Encoder
(Off-Gimbal Unit)

Multipath propagation effects also created more difficult field operations than anticipated, requiring use of the line-driver output signal for some checks. Countdown [illegible] for the scheduled launch sequence in mid July, but problems were evident in the [illegible] booster control system and the launch operation was postponed.

The mission was rescheduled for fall of 1982 and two men (with the associated GSE [illegible]) again provided at the WSMR facility for 46 man days of support. After [illegible] checks and calibration, a dress rehearsal count went smoothly and [illegible] count commenced the following day. The SPICE-2 payload was sucessfully [illegible] Aries vehicle A24.7S2-3 at 0347 UT on 15 September 1982. Vehicle [illegible] flight was nominal with apogee at 373 Km and satisfactory performance [illegible]. The radar beacon in the payload did not perform properly, and radar [illegible] data appeared to indicate premature impact, so recovery was first believed [illegible] due to parachute failure. However, it was found the following day that the [illegible] properly released, but deployed late in the flight, permitting good [illegible] payload, and the mission was classified as a success.

[illegible] the recovery, some initial design efforts were devoted to development of a [illegible] for a following flight as SPICE-3, but this work was terminated due to [illegible] follow-on launch plans.

The development of a special GSE system for the SPICE program was performed concurrently with the development of the airborne system. The system was designed to select words from the incoming serial PCM data stream and store them at rates up to 200,000 words per second. Stored data could then be analyzed by an associated computer system, converted to the desired form, and displayed on either a digital plotter or put in permanent record form by a line printer. A special OSU-designed decoder was to be used, operating as a complementary device for the format selected. The decoder was an updated version based upon the existing OSU model D90RP21 single-channel design, incorporating some of the features of the DAC-20 design and some special features for this particular use. Panel switching could permit use of an internal bit synchronizer with the capability of operating in any standard Bi-Phase or NRZ format at rates up to 2 Mbps, or optional use with an external bit synchronizer. Frame sync patterns up to 32 bits in length could be programmed for the desired pattern, and word lengths up to 16 bits could be chosen. Minor and major frame lengths of up to 99 were accommodated, and any single word from the minor frame (or chosen from subcommutated data within the major frame) could be selected at will, with the digital value displayed in binary form on an array of lamps. A single 12-bit DAC was to provide the analog equivalent of any selected word, and the unit was so designed as to permit its use with the available DAC-20 or Eight-channel outboard DAC units for expansion as a stand-alone system.

However, the decoder was principally intended as the front-end for a special data sorter box. In this mode of operation, the decoder locked on to the incoming serial stream and, operating in the "all-words" mode, fed a parallel set of data and address lines, updated at incoming word rate, to the data sorter box. This data sorter/storage unit, operating under control of the associated computer, could select up to 64 desired words from the stream and store the desired data and addresses in an expanded Trans Era auxiliary memory module which provided 64 Kilobytes of RAM, with an associated controller and 448K of auxiliary memory. (This would provide up to 225 seconds of storage for a single selected word up to 16-bits in length at a rate of 2000 samples per second, or approximately four seconds of stored data if the maximum of 64 words were being selected and stored.)

Stored data was fed to a Tektronix 4054 computer with auxiliary memory and a Tektronix 4052R08 Signal Processing ROM pack for Fast Fourier Transformation. With the appropriate printer interface and the Tektronix 4663 Interactive Digital Plotter, processed data could not only be observed on the 4054 CRT display, but also provided as hard copy output.The Tektronix 4054 computer was selected because of its speed and

flexibility, and provided the capability of displaying up to 4000 data points horizontally on the built-in CRT. Speed was adequate to permit conversion from digital binary input to spectral form via the Fast Fourier Transform program and display of the spectrum in 20-25 seconds; several words could be analyzed and displayed for correlated analysis. The overall system was operable from either realtime data streams from the payload, or in tape playback modes. An option was provided for correlation of converted data points with IRIG B time code through an expanded program for the 4054 computer; this was of particular import in playback of data from magnetic tapes, as it permitted the data sorter/storage module to operate under computer control, being held in a standby mode during playback until a desired IRIG time signal was recognized, then sorting and storing the desired data from the tape and signalling the computer that data was available for conversion as soon as the desired data was in storage. Both IEEE and RS232C interfaces were provided for use with the associated plotter and line printer, as well as the standard OSU parallel interface connections for stand-alone use with auxiliary DAC or Bar Graph display systems.

Following the initial design study and preliminary development work on the required software, some breadboard checks of circuitry planned for the hardware were performed to demonstrate feasibility, and budgets prepared for the provision of such a system to be used in the SPICE program. Budget estimates indicated an anticipated development cost of approximately $56,700 for the OSU-built decoder and sorter/storage system. Auxiliary equipment from Tektronix and Trans Era was quoted at an additional acquisition cost of approximately $45,500. Since funding for implementation of such a system was not then available from the sponsoring project, the development was terminated.

3.2.5 Background Equatorial Astronomical Measurement Program Work.

Support services supplied under the BEAM program included coordination for the anticipated future program, preliminary design studies for a custom PCM encoder subsystem for telemetry, modification and qualification testing of commercially procured PCM encoders for use in the payload, and modification of the existing Minitracker II autotrack antenna system to provide increased range compatible with the anticipated performance of the vehicle-payload configuration, thus providing improved support capability at the selected NRR launch site.

The earlier development work in support of the BEAM program represented an extension of the "Hi Star South" program which was supported under an earlier AFGL contract, F19628-72-0139 (Ref. 1). The project was initially referred to as the "High Star South II"

project and was planned as a South American follow-on to the Australian program of 1974, using the updated and refurbished sensors recovered from the Woomera flights. In the initial planning, a custom telemetry subsystem which was to include a high bit rate 10-bit resolution PCM encoder and incorporate the modified PCM ranging technique (see section 4.3.1 of this report) for trajectory determination was proposed. Preliminary development of this design was terminated by the decision to utilize existing commercial PCM encoders residual from the SPICE-1 mission.

The available SPICE-1 components were procured in two different versions: one was manufactured by Teledyne as their model DS-726 (98571) and chosen as the prime unit for flight; a second version manufactured by Vector as their model PDS-700-8 was to be used as a back-up component. These two encoders, although similar, differed in several respects. In order to bring both units into accordance with Rockwell International Corporation Specification VC409-0001-27 and meet the mission requirements, OSU was asked to standardize the input/output interface details, convert the PCM output to NRZ-S format, and perform full qualification testing on both units. The code converter was provided as an auxiliary unit for inclusion in the payload system and the circuit is as shown in OSU drawing B42BA01. Both encoders were to provide a format at 960 Kbps with 10-bit word length, 64 words per minor frame, and a 32-frame long subcomm in word three. To convert to the desired NRZ-S format, the NRZ-L output stream and bit clock signals were taken from the parent coder through an OR-gate to a JK flip-flop as a code converter within the B42BA01 unit. The converted NRZ-S output wave train from the flip-flop then was fed as input signal to a pair of line-driver amplifiers. One was provided with an amplitude adjustment and fed a separate connector, for use as the modulation signal to the associated S-band transmitter. The second line driver provided a standard fixed amplitude signal to another separate coaxial connector for use as a hard line monitor signal. Each code converter also included an internal DC-to-DC converter in order to provide all required operating voltages from the raw 28 volt DC power bus; the interconnecting cable to the parent encoder was as shown in OSU drawing A42BA01. Data input connector assignments to the parent encoders were rewired to standardize the interface assignments, and both systems were then subjected to full qualification testing by a special software routine developed to permit use of the automated test routine described in Reference No 10; the interface cabling required for this test is documented in OSU drawing B42BB01. The qualified systems were delivered to AFGL. The Vector encoder was subsequently returned to OSU with a request that it be rewired again to the original input connector pin assignments. This rewiring was verified by local tests of the remodified coder and delivery made to Rockwell International without repeating the full

qualification test procedure.

In connection with a coordination trip to Sao Jose dos Campos, Brazil, for preliminary program planning on the HARP mission (Ref. section 2.1.3), the anticipated launch support requirements for the BEAM mission were reviewed. Because of the flight profile anticipated with the Lance vehicle and the BEAM payload, the slant range coverage provided by the standard 4-foot parabola antenna used on the Minitracker antenna appeared marginal and 3 db improvement in autotrack antenna threshold sensitivity by changing to a 6-foot diameter parabola was proposed.

Previous experience with the larger diameter reflector existed in the special Model N-1 Minitracker constructed for NASA (Ref. section 1.4.2 and Figure 8), but the NASA design involved other special features not required in this application and modification of the existing Minitracker II was undertaken to utilize existing AFGL equipment in the OSU inventory. A first check was made by modifying the pedestal riser by installing a ten-inch long extension between the standard pedestal and the Az-El head assembly, then adapting the mesh dish from the TRATEL I antenna for mount on the Az-El head by bolting extension arms to the dish flange. The lighter weight of the mesh dish was such that no change was required in the torsion counterbalance system.

Since tests of this temporary system revealed that the desired performance could be obtained, but shipment of the system would be quite difficult with the rigid large reflector, a change was made to use a commercial Watkins-Johnson model 626099 reflector. This dish is of fiberglass honeycomb construction with a metallized reflective surface and built with a circular center section and six extension wings, which can provide a six-foot diameter parabola with 27.5 inch focal length when assembled, but also permits quick disassembly into a compact form for shipment. Again, the weight is so low that, even with the increased moment arm due to extending the S-band feed farther from the elevation axis to match the increased focal length, only a small counterweight was required. An X-shaped crossbeam structure mounted to the circular center section not only adapts the parabola mount to the Az-El head of the Minitracker, but provides the mechanical support for the quadrapod booms needed to support the feed at the proper point. Mechanical details of this structural change are documented in the OSU X42BTXX series of drawings. The Minitracker feed had previously been modified to include filtering and improved preamplifier changes and is usable with no further changes.

In order to improve the uplink range for the associated TRADAT system so that it can be used with the increased downlink range provided by the larger relector, a power amplifier will be added to the uplink ranging system. The Henry Radio model 2004A amplifier

selected for this purpose will provide 300 watt continuous power at the 550 MHz uplink frequency, and can be driven by the standard model C95AL01B multifrequency transmitter (Ref. 4.2.2 of this report) as an exciter with no further change to the system.

3.3 BAMM and Balloon Mission Support Work.

A number of projects within this reporting period were related to missions in which the vehicle carrying the measurement payload was a balloon, rather than a rocket. The primary effort in this area was for the Balloon Altitude Mosaic Measurement progrm, which had originated under earlier AFGL contract F19628-75-C-0084 (Ref. 2); the BAMM program continued with the BAMM II and BAMM IIA flights under this contract. Related support efforts were supplied in providing assistance for the Stabilized High Altitude Research Platform (SHARP) program during tests of the system which was developed to carry the modified BAMM intrument. Two balloon-borne test flights of an experimental system under development for use in providing range and trajectory measurements through asynchronous PCM telemetry downlink systems were also made during a BAMM II launch mission. One other program (CN2) in which a series of balloon-borne measurements of temperature in the mesosphere were performed also received support in the form of some last minute modifications to the payload ranging subsystem and by field support with modified tracking and trajectory ground systems.

3.3.1 The BAMM system required a special PCM encoder which provided two synchronized PCM-encoded links of telemetry data at high bit rates, with many special features developed for this particular application. The coder was regarded as a "state of the art" device when originally developed in the mid-seventies, and was the subject of a special Technical Report prepared for AFGL under contract F19628-75-C-0084 (see Ref. 12). A photograph of the BAMM subsystem components developed for this purpose is shown as Figure 3, which depicts both the dual PCM encoder and the associated remote unit used to process housekeeping data for insertion in the PCM downlink data.

The BAMM encoder was unique in the requirement for accepting not only analog input signals for conversion and storage, but also to accommodate asynchronously generated digital inputs from an onboard interferometer as part of the primary scientific data to be transmitted. The interferometer data was generated by an instrument which scanned by

Figure 3 BAMM IIA PCM Encoder (with Remote Unit)

a mechanical drive system (which was unpredictable in timing and not synchronized with the main timing system). This required a complicated digital storage system within the encoder, through which the data could be clocked into storage as it was generated within the instrument, then read from the storage register and transmitted back to earth at the synchronous rate of the PCM subsystem. The buffered storage system internal to the encoder stored 1024 words of 14-bit length and also generated the appropriate addresses for such storage, as well as overflow indicators in the event that the digital data was clocked in faster than it could be transmitted back, thus saturating the register. A second radiometer instrument aboard the same payload used an array of sixteen infrared sensors, each with four gain factors for analog output sensitivity; the encoder was to select the gain factor of interest from the four available analog signals, encode the selected data to 12-bit accuracy in digital form, and transmit the selected data with two additional bits inserted at the end of the data to identify in binary form the selected scale factor. In addition, associated housekeeping data was provided in the form of both digital data and remotely generated analog signals, which were to be selected and encoded to 12-bit accuracy.

The encoder operated at the high rate of 1.344 Mbps for two synchronized links, each in NRZ-S format, using 14-bit words and 11 words per frame, in order to provide the desired sample rate and resolution within the bit rate limitation imposed by the associated magnetic tape recorders. Low sample rate requirements for the houskeeping data were

met by using subcommutation, with a major frame length of 64 minor frames selected to provide this capability. Word zero was assigned for frame synchronization in each link, and word one was used to provide both SFID (with six binary bits to identify frame number) and eight following flag bits of binary housekeeping data in both links. Word two was identical for both links, providing an element of redundancy for the experiment. This word was used to transmit the digital instrument data for the first 48 frames, provided eight spare words for future assignment, and transmitted the housekeeping data in the remaining eight frames. Words three through ten were so assigned as to provide the selected data from eight of the 16 IR sensors on each of the two links, again providing some degree of redundancy to the system: In the event that one of the links should fail, the interferometer data, half the radiometer data, and all housekeeping data could be retrieved from the other link. An additional requirement was that uplink command signals from the ground receiving system could be used to select either of two scan rates for the interferometer, or to inhibit the autorange selection feature and lock the infrared sensor data to one of the four available sensitivity factors. The associated remote housekeeping module derived timing signals from the main encoder, multiplexed data inputs to the 10-bit housekeeping A-to-D converter, and clocked the converted housekeeping data back into the main encoder in serial form. Further details and operating circuitry for this telemetry subsystem are provided in Reference 12.

Throughout the BAMM program the original two-link encoder has been repeatedly modified and refurbished for reflight on each following mission. Believing that advances in technology during this program had been substantial enough to warrant replacement of the original encoder with a new design, the instrument requirements and available components were reviewed and development of a more modern replacement design was done during this contract period. The major change developed in this program related to the onboard storage buffer, which was to utilize only four chips, each handling 1024 4-bit bytes of data. The addition of redesigned addressing for this buffered register, with high-speed tristate logic, permitted a total reduction of fifteen in the chip count for the encoder and also permitted a sizable reduction in power consumption, size, and weight of the encoder. The proposed circuitry was tested in laboratory development form and a recommendation made that the earlier design be retired and a change made to the newer design for the BAMM II program, but funds were not available for this purpose and so the original encoder was simply refurbished and flown again on the later missions.

As indirect support to this program, an existing support trailer which had been stored at OSU was modified for use as an auxiliary mobile station for balloon missions. The trailer

was made more usable for this purpose by stripping out the original bulky equipment racks which had been required in previous usage. The floor plan was modified to permit installation of work-benches and storage cabinets along both walls, with a center island installation of two blank racks with AC power regulators and wiring provided for quick installation of the related GSE for each mission. Lighting was also revised, with a special storage rack for the flourescent lamps during shipment. Special shipping provisions were also made for other items normally used in this support, including spare parts and manuals. A TRADAT ranging system was installed for use with the associated tracker used to acquire data from the balloon, and a number of other features of special interest to the balloon program were provided. In connection with this revision, a special mount for a TV camera on the tracking antenna was provided as shown in OSU drawing B95AA04. This trailer was then used in all following balloon support missions.

Direct support for the BAMM program early in this contract period included the requalification of the coder recovered from flight in the preceding AFGL contract after rewiring the input connectors to accommodate desired changes in the data format. One man was then supplied at Roswell, New Mexico for three days in the summer of 1981 for coordination of BAMM program plans for the forthcoming launch of the BAMM II payload from the Chico, California site. (During this same trip assistance was provided in the launch of a related balloon from the Roswell site.) One man was later provided at the AFGL facility for thirteen days during integration and calibration testing of the BAMM II payload before shipment to the Chico launch facility. During this trip the TV camera mount was installed on the tracking antenna, tests on the TRADAT ranging system were performed, and coordination proceeded concerning the test flight of the modified developmental PCM ranging system (see section 3.3.3) during the Chico launch mission which was soon to follow. After completion of these tests, all required support equipment (including the TRATEL tracking system, the modified support trailer, the two TRADAT systems for ranging on both the normal system and the experimental PCM system, and all associated GSE for reception, decoding, display, and magnetic tape recording of the data) were shipped to California. Two men were supplied at the Chico launch site for prelaunch testing and launch assistance for a period of sixty man days. Successful launch for the BAMM II payload aboard balloon H82-11 was accomplished at 1130 UT on 30 April 1982, with successful recovery of the payload following flight.

The next following support for this program was a planning meeting for reflight of the system as the BAMM IIA payload; this meeting was held in conjunction with the SHARP system critical design review meeting (see section 3.3.2 below) at the PSL facility in

New Mexico and required the presence of one man for four days in the fall of 1982. Based upon the requirements established in this meeting, the encoder was again refurbished to provide the desired data format and completely requalified for flight, then redelivered for payload testing. The scheduled launch plans were later modified and one man again supplied at the PSL West facility in New Mexico for four days in the spring of 1983 for conferences concerning several alternate plans for mission objectives and rescheduling. This meeting was followed by delivery of the BAMM encoder, modified and tested again to permit flight use in further testing of the SHARP system by a flight program which would precede launch of the BAMM IIA instrument. A simplified data handling requirement existed for this test flight, since the interferometer was not to be flown at this time. The data format was accordingly modified again and the encoder requalified and redelivered to PSL for the SHARP flight (see below); after recovery from the SHARP flight the encoder was again changed to the desired BAMM IIA configuration, subjected to qualification tests, and redelivered to PSL for installation. Finally, one man and the required GSE were provided at the Naval facility in Corpus Christi, Texas for 42 man days to assist in the field testing and launch of the BAMM IIA payload. Repeated delays occurred due to poor weather and a later rupture of the balloon envelope during one launch attempt on 24 May 1984. Successful launch of the balloon payload occurred at 1111 UT on 1 June 1984. Following partially successful recovery of the payload, at about 1900 the same day, a post-launch conference was held to evaluate performance and the mission was terminated the following day.

3.3.2 Assistance on the SHARP program was provided as an auxiliary service under the BAMM major program. The SHARP platform was developed by PSL for use by AFGL in the later BAMM missions. One man had been provided at the Critical Design Review meeting for the SHARP program in a four-day PSL meeting in late 1982, as mentioned previously. OSU originally was scheduled to provide assistance in this program in the fall of 1983, but the "stop work" order which was issued because of a critical fund shortage late in the fall of 1983 had precluded these services at the time of the next scheduled SHARP meetings in September of 1983. However, as described in section 1.4.5 of this report, coordination for both SHARP and BAMM IIA missions occurred as related work under sponsorship of USU and continuity of the mission effort was maintained. Later in the fall of 1983, when new funding had been established for the following fiscal year, the same man was again provided at the PSL site for nine days to assist in the integration testing which preceded the test flight from the Holloman Air Force Base in New Mexico. (The minor changes and testing of the encoder required for this flight were discussed in describing the BAMM encoder modifications in the previous section.) One

man and related support equipment were again provided for fourteen days at Holloman to assist in the SHARP launch program. The SHARP test flight was accomplished in February of 1984; although the telemetry and ranging systems functioned as desired, the tests were only partially successful due to difficulties with the related command system, which also impacted the recovery mission. However, the encoder was successfully recovered and refurbished after flight for use in the following BAMM IIA mission.

3.3.3 The experimental PCM ranging system described in section 4.3.1 of this report was also tested in conjunction with the balloon support program. The first test flights of the system were performed by use of a test package developed for flight on preliminary test balloons which were scheduled for launch prior to the BAMM II flight from Chico, California in the spring of 1982. The test package consisted of a small platform which included a ranging receiver aboard the balloon, and two downlink S-band transmitters. The received coded ranging signal from the uplink transmitter in the TRADAT ground station was relayed back to the ground in the normal TRADAT V system by a transmitter operating at 2279.5 MHz, where it was received by the TRATEL IA antenna, fed through a multicoupler to a standard receiver operating at 2279.5 MHz and then used as the downlink stop signal to the normal TRADAT V system to provide a reference trajectory calculation in the manner normally employed for flight. The output from the balloon-borne receiver was also processed and used as input to the modified PCM ranging system described in section 4.3.1, where it was used to develop the ranging flag in the C42PA01 PCM encoder output and also to operate the interval counter which measured delay before retransmission in the model C42PD01 ranging decoder in the balloon. The delay interval was then inserted in the PCM data from the encoder and transmitted on a second downlink of 2251.5 Mhz. A second receiver on this frequency was used with the TRATEL IA multicoupler to drive the modified TRADAT IV/KIM-4 ground station, from which the comparison trajectory data could be determined.

The experimental system was twice flown in April of 1982 and the desired comparison trajectory data successfully recorded in both flights. The first flight occurred aboard balloon H82-08 on 20 April and, after recovery and brief tests to insure the system was still operational, it was again flown aboard H82-09 on 24 April 1982. Post-flight data reduction of the magnetic tapes from these two flights verified the design concept being tested. The trajectory data from the experimental modified PCM system disclosed somewhat less range jitter than shown in the standard TRADAT V system in the test flights. Less long term drift in the ranging data during the lengthy flight periods was also noted for the experimental system, but the usable tracking threshold sensitivity was

3 to 4 db below that obtained through the standard TRADAT V system. Since the two transmitters had equal power output and similar antenna systems, it is believed that this loss in threshold may have been due to the modulation level which was employed for the experimental system.

3.3.4 Support of the CN2 program was primarily in the form of manpower and equipment for the launch of a series of balloon-borne thermosonde instruments. Some payload work was also involved due to adding (in the field) special OSU-developed 403 MHz preamplifiers to the ranging receivers used in these payloads. Support activities included supply of the TRATEL II tracking antenna and TRADAT V trajectory systems for acquisition of data and determination of flight trajectory elements, operated in conjunction with the AFGL van station as the field control and data recording center. One man was supplied at the AFGL facility for five days during tests and launch of two payloads in this program (Ref. 2.2.1 of this report). Two men were later supplied at the NOAA facility near Boulder, Colorado, for 47 man days (Ref. 2.3.8). Fifteen additional payloads were launched during this portion of the program in March of 1983. Although only partial success was achieved because five balloons burst, one instrument failed, and there was some trouble with the ranging equipment on two flights, the overall mission was considered successful and tracking extended to a maximum of 130 kilometers range on the longest flight.

3.4 Internal Laboratory Services Project Support

A number of projects during the period reported were in support of internal projects by the various laboratories within the AFGL organization. As in the case for BMP support, some of these represented a continuation of projects which were underway at the time this contract period began. Others arose as short-term projects completed within the reporting period, and still others remain incomplete and will be continued on into the next following contract. The scope of these individual projects varied, ranging from simpler projects which involved only field support at the launch site to complex tasks in which it was necessary to develop equipment through a study phase, then construct, qualify, and build flight components, then provide support services during the preparation and launch phase.

3.4.1 Falling Sphere Program Support Services

The ongoing Falling Sphere program continued throughout this period of services. This project, conceived as a method of measuring the density of the atmosphere by detecting drag deceleration upon a freely falling body through use of a sensitive 3-axis

accelerometer within an ejectable instrumented sphere, has permitted a simple "Piggy-back" experimental program, in which a self-contained subsystem may be flown as a daughter payload, installed as the nose section aboard vehicles allocated for related experiments. This program required OSU to provide the vehicle support system for the sphere in earlier work (Ref. 2, section 3.1), but was later shifted to a program under which this laboratory also supplied the special PCM encoder for the telemetry within the falling sphere (Ref.3, section 4.4). OSU later became responsible for the special FM/FM telemetry system within the sphere, using a three-channel subsystem and 2-watt transmitter. This permitted a refinement in the experimental technique, by which dynamic variations in the drag could be sensed by an added dual output wideband Z-axis accelerometer within the same sphere (Ref. 3, section 5.7). Services provided within the contract period being reported included construction and qualification testing of the PCM encoder, set up and qualification of the telemetry subsystem, provision of the required special GSE, and support services during the launch phase at remote sites in a number of campaigns. Some special GSE was also developed to facilitate field support for this experiment at overseas sites by a minimal crew with a compact ground station.

The design and construction features of the special OSU Model C40BE02 PCM encoder developed for this application has been completely documented previously in Scientific Report No. 2 to the preceding AFGL contract (Ref. 13). The format used is a 20 Kilobit per second Bi-Phase Level code, with 16 words of 10-bit length per minor frame. Word zero is allocated for frame sync, and uses frame alternating complement synchronization to improve reliability. Word 15 is allocated for subcommutated monitors, making use of the eight frame interval provided by the major frame length. A bipolar A-to-D converter within the encoder allowed frame zero synchronization by "all zero" coding, since it could be saturated at the negative end with a reference voltage, but all of the housekeeping data was positive in sense. Seven housekeeping inputs could be accommodated without the necessity for a special SFID word assignment.
(Subcommutated monitors in word 15 were not used in the five encoders flown in this program, however. Word 15 was reassigned as a continuous ejection monitor.) The remaining 14 words were all primary data, permitting bipolar accelerometer inputs of ± 5 volts DC at a sampling rate of 125 per second. Six additional encoders (serial numbers 5 through 10) of this design were constructed for use in the falling sphere project during the contract period. All were qualified for flight by use of a new automated test routine, developed to permit more extensive testing than was permissible under the older method of manual testing. The tests used a special routine with the computer-controlled system reported earlier (Ref. 10). Five of the new coders were installed in spheres AC-8 and

AC-15 through AC-18; the sixth system was used as a field spare and remains available for use under a following project.

The telemetry subsystems used on this project have also been described previously (Ref.3, section 5.7), but the modulation taper and level were redefined for optimum use by experimental determination of the values which could permit data retrieval from all three subcarrier oscillators at the data bandwidths desired. Vector Model MMO-11 "Microminiature" oscillators were used with the associated MMA-12 wideband mixer-amplifiers in a four-position Model 652-4 mount in the following configuration:

IRIG No.	Freq.	Dev.	Data	Bandwidth
16	40 KHz	38 KHz	Wideband Accel, Lo Gain	1.6 KHz
18	70 KHz	56 KHz	Wideband Accel, Hi Gain	2.1 KHz
H	165 KHz	250 KHz	PCM data, 20 Kbps	24 KHz

This system provided the desired mix of output signals and, with proper adjustment of the level control (approximately 2 volts peak-to-peak), gave an overall transmitter deviation of ±344 KHz on the S-band telemetry link from the sphere. Tests with the GSE normally used as a ground station indicated that this resulted in a station threshold of approximately -102 dbm to give noisy data from all three channels with the desired data bandwidth for each; i.e., the two analog channels, although opened to much wider bandwidth than normal, dropped out at the same low signal level as that which resulted in lock-loss for the PCM data. (It should be noted that this was essentially a system test, and the empirical values determined were for the preamplifier, receiver, discriminator with associated low pass filters, and PCM decoder used both for testing and in the field operation.) The transmitter used was the Vector Model T-202S, and typically gave a measured power output of 3.1 watts into a 50 ohm load. Total power drain was approximately 1 ampere from the 26-32 volts DC supply within the sphere. Six telemetry subsystems were supplied, assigned as noted for the associated encoders in the preceding paragraph. All received normal qualification testing prior to delivery.

Special items of ground support equipment were also developed in the course of this contract period. These included a compact telemetry simulation system which did double duty as a laboratory test system and, during field support missions, served as a combination signal simulator for set-up of the analog channel galvanometer displays and FM/FM multiplex system for tape recording of station housekeeping data. Special Y-harness cables were also built to permit the older Brush Model 260 (6-Channel) pen recorders to display slow speed time code data on one marker pen and "Zero time" reference markers (synchronized for two Brush recorders, the Bell & Howell Ultraviolet

Oscillograph, and the station local time display) on a second marker pen of each Brush. A dedicated PCM decoder (Ref. 14 & section 6.3.1 of this report) which provided a flexible unit for testing encoders and displaying the digital data was also developed and constructed, as was a special 4-channel "Minirack" for Tricom Model 442 discriminators (see section 6.2.1). All of these items were of assistance in minimizing the logistic problems of shipping a self-contained ground station to the remote launch sites and provided a compact ground station which could conveniently be operated by a one-man field crew. Later, for the MAP/WINE campaign, one additional piece of GSE was developed for use with smaller met rockets, and three of the resultant Model C42DD01 "DART" Thermosonde Data Converters (see section 6.3.2) were constructed and delivered for use by University of Bonn personnel during the MAP/WINE field mission.

The telemetry simulation system is depicted in OSU drawing C99VT01. It was built from a modified telemetry test harness and 8-position Vector Model Model M-143A mount. An external source of +28 volt DC power is required (and available from the 442 "Minirack" described later). This voltage, fed through the control box portion of the system, not only provides switchable power to the test system, but also is down-regulated to supply the calibration voltages of 0, 2.50, and 5.00 volts for the associated subcarrier oscillators and an offset voltage of 2 volts for the multiplexed station AGC voltage. The mount accommodates a mixer-amplifier and seven subcarrier oscillators. Three positions are so wired as to connect their output signals through an adjustable resistance mixer as a simulated sphere FM/FM composite video signal, switchable for calibration voltages at band center, lower, and upper band edges for the Channel 16, 18, and H subcarrier oscillators; this section provides a convenient source for set-up and calibration of the associated discriminators and analog recorders used in the ground station. The remaining four subcarrier oscillators are wired through the mixer-amplifier to a composite output connector, and have their inputs switchable between individual multiplexed data inputs and the same three calibration voltages available for the simulator section. These four are normally used to combine station AGC, local OSU time, range time, and voice signals into suitable form for recording on magnetic tape. A branch of the cable between control box and mount is properly wired for the S-band transmitter input connector, so that (if desired) the telemetry transmitter for the sphere may also be tested with the composite modulation supplied from the mount.

Test harnesses were constructed to permit synchronized use of marker pens on the older Brush Model 260 recorders for externally-supplied time signals and event markers, thus retaining all six available data pens for use on decoded PCM data. (This was a problem

with the older AFGL Brush instruments because they did not have optical isolators on inputs to the markers, but instead relied upon swich closures to a -32 volt solenoid circuit for marker activation.) Each Y-harness used a 12 volt relay with double-pole, double throw contacts to provide the synchronized and isolated closures to the two associated Brush recorders. For slow code range time signals, the range time signals were used as modulation to one of the multiplex oscillators, and the associated multiplex discriminator used to detect the timing and drive one relay coil. This arrangement allowed use of real-time or playback multiplex signal, provided the isolation to the recorder inputs, and simplified station cabling for real time/playback turnaround. A second Y-harness was also provided, with the relay coil connected to the "reset" switch of the H-P 5521A counter which provided the local station OSU timing. This "Reset" switch completed a 30 volt circuit internal to the counter to rezero the counter each time it was depressed, and so provided a reference time on the digital readout, the multiplexed OSU time code, and all associated recorders.

The discriminator "Minirack" is described in section 6.2.1 of this report. It not only provided a compact group of discriminators for use in the ground station, but also served as a convenient general purpose ground station item, with built-in switching designed to simplify station cabling and operation. Three discriminators were allocated for the received signals from the sphere, and the Channel H output was taken through a switch to the associated PCM decoders, with a PCM simulator input transferred to the decoder input in the "test" mode of this switch. The PCM simulator signal was provided by the field spare encoder, which received power from the "Minirack" and provided a convenient source of PCM in a format identical to that received from the payload. A fourth discriminator was allocated for demultiplexing the station housekeeping data, and could be used to drive the Y-harness described above for providing local timing on the marker pens of the Brush recorders. Addition of a built-in 5-channel calibrator, switchable as a substitute for the received FM/FM data, further enhanced the convenience of this unit, providing a very compact item for the ground station.

The special PCM decoder developed and supplied for this project is described elsewhere (Ref. 14 and section 6.3.1 of this report). This decoder was complementary to the sphere encoder, hard-wired for the standard format used, including the frame alternating complement synchronization and available word 15 subcommutation. Eight analog outputs were provided to drive analog recorders. Two of these were permanently connected to convert the digital data from words 13 and 14 to analog form by 8-bit DAC outputs, providing analog nutation and voltage monitor data at all times. The remaining

six were switchable to any desired word within the format; two of these six used high-resolution 10-bit DAC circuits and also provided a digital binary lamp display of the selected word, while the other four used 8-bit resolution and provided analog outputs to the associated recorder only. Additional features included a parallel output connector for interface to the computer-controlled qualification test set-up, a built in calibrator, and auxiliary circuitry for a preamplifier and a separate line driver. This decoder not only provided a flexible and compact unit capable of driving either an 8- or 6-channel pen recorder, but also was used at OSU for checkout and qualification of the encoders constructed for this program.

The DART Thermosonde Data converter is also described elsewhere (Ref. 16 and section 6.3.2 of this report). The system was developed specifically for use in the MAP/WINE campaign, which was to include a large number of smaller meteorological rockets supplied by the Space Data Corporation (SDC) for the desired temperature measurements in the upper atmosphere. The data from these small rockets was in the form of pulse repetition frequency modulated data on a carrier frequency of 1680 MHz. The data converter was designed to accept the associated receiver output, count the number of pulses received per second, and convert the count to an analog signal suitable for strip-chart recording. An internal calibrator was also provided, with crystal-controlled reference signals available to the counter from a panel switch at 0, 100, and 200 pulses per second. Three of these units were built, to be used at each of the three launch sites scheduled for DART launches in Scandinavia during the MAP/WINE program.

Field support for the falling sphere program was extensive in the course of this contract. The sphere aboard A10.903 in the Auroral Energy campaign was given support in Alaska during the early days of this contract, as a carry-over from preceding contract F19628-C-78-0033. Support was later supplied at AFGL for integration tests on a number of payloads in this series, followed by launch support for the TRACER, CAMP, STATE, and MAPWINE programs at various launch sites as detailed below.

Integration testing for sphere AC-15 in the TRACER program was done at AFGL, in conjunction with the testing for AC-16 in the CAMP program, during a 5-day period in the spring of 1982. Following successful tests of both associated payloads and the piggy-back sphere systems, which included shock, vibration, and pyrotechnic circuit tests, the necessary GSE was shipped to the Wallops Flight Center in Virginia (operated by NASA) and one man was supplied for 14 days to assist in the prelaunch tests and flight data retrieval. Rocket A13.277, ejecting sphere AC-15, was successfully launched at 0201 UT on 29 June 1982. An apogee of 150 Km was achieved, and good data resulted.

The airborne equipment for the CAMP program underwent the testing in the same program as that for TRACER. Equipment was then shipped to the Esrange site in Kiruna, Sweden, operated by the Swedish Space Corporation, for inclusion in the extensive launch sequence planned for this mission. As in the case of the earlier Energy Budget Campaign, this program was planned to involve both Esrange and ARR sites in the simultaneous launch of a salvo of related instrumentation on a large group of rockets, during a period when noctilucent clouds appeared over northern Scandinavia. One man was supplied at this location for 47 days in support of the overall mission. Data retrieval for this flight involved a remotely located 1.25 meter S-band parabola and receiver. The antenna was mounted on a pedestal near the radar site, approximately 2.5 Km from the remainder of the ground station complex, and tracking was controlled by slaving the pedestal to the radar. A number of small SDC met rockets (inflatable spheres and thermosondes) were also supported during this same mission, but no special ground terminal equipment was supplied for this purpose. After a lengthy delay awaiting the proper conditions, the TAD payload (from which sphere AC-16 was ejected) was finally launched as part of the main CAMP salvo at 0016 UT on 4 August 1982. Although a successful flight to an apogee of 153 Km was achieved with good data, the signal from the remotely located antenna was poor in quality and data retrieved from playbacks of data recorded at the German telemetry station operated by DFVLR was used.

The next mission in this series was that for the STATE program. Although the equipment supplied from OSU was used in the AFGL integration test program, no OSU personnel were provided for these tests. All necessary GSE was then shipped to the PFRR site in Alaska, and one man was supplied for support for 10 days during the prelaunch tests and flight of A11.074. This rocket was successfully launched at 0651 UT on 16 June 1983, ejecting sphere AC-17 in conjunction with MST radar soundings and the related launch of a number of smaller met rockets. Apogee was 135 Km; upleg data was rather spotty, but good data was achieved during the downleg and the mission classed as a success.

The MAP/WINE campaign was the most elaborate of the programs undertaken in this project. Again, an elaborate program to involve the sites at ARR, Esrange, and Lista, Norway, was planned. Launches were to occur in several salvos during geophysical conditions of interest, in conjunction with instrumented aircraft flybys and atmospheric soundings from LIDAR and MST radar installations. Two complete piggyback systems received full normal testing at the AFGL site in the fall of 1983, even though the full integration test procedure could not be followed because the mother payloads and rockets were already in Norway for testing at this time. One man provided assistance in these tests for five days. After shipment of all airborne and ground support equipment to

the ARR site in Norway, one man was supplied for a period of 78 days in support of this program, which was scheduled to include approximately 135 rocket launches. A large number of small SDC-supplied met rockets were again involved, including both inflatable spheres and DART thermosonde rounds. Both launch support and GSE were supplied for this purpose during the mission, and some modifications to the smaller rockets were made to improve performance prior to scheduling the two main salvos, which were dependent upon occurrence of a stratwarm event and were delayed for some time. Sphere AC-8 was eventually launched aboard the MM-1 rocket at 1853 UT on 31 January 1884, during major salvo D. The sphere ejected normally and achieved an apogee of 113 Km, providing good data throughout the flight. A second Nike-Orion rocket, MM-2 carrying sphere AC-18, was successfully launched during salvo R1 at 0305 UT on 10 February. Ejection was normal and an apogee of 114 Km reached; data was poorer in quality than that from the earlier AC-8 instrument, and the comparatively poor pattern of the AC-18 S-band antenna was suspected as responsible for the spotty data. However, enough data was gathered for scientific success.

3.4.2 Miscellaneous Launch Support Activities.

A number of missions required support during this contract, but were not major projects in which OSU had constructed equipment under the terms of this particular contract. These support activities were primarily involved with the supply of equipment and personnel to provide additional launch support services at remote sites in Alaska or Canada, and in all cases were provided to AFGL in conjunction with deployment of the Minitracker remote station for autotrack data acquisition of S-Band data from payloads constructed and deployed for AFGL launch by other related agencies.

The first series of payloads for which such support was supplied was the entire sequence of Auroral Energy payloads at the PFRR facility. This mission was underway at the time activities commenced under this contract; OSU personnel were at the launch site with a full two-station Minitracker/TRADAT complement of GSE and awaiting the occurence of the desired AuE event. The elaborate set-up of equipment was due to the fact that a salvo of four major rockets with correlated payload instrumentation was to be launched within a 30-minute period when the desired conditions were achieved. Trajectory data was both by beacon transponders and TRADAT for various portions of the salvo, and several of the vehicles used more than one S-Band downlink. The OSU stations were assigned both prime and back-up capability in this series of launches. Three of the four vehicles also carried equipment which had been built at OSU under the preceding contract, F19628-78-C-0033, and were reported in the Final Report for that contract (Ref. 3).

The extensive support requirements for this mission required a five-man crew during the period of 7 February through 13 March 1981, to provide both tracking and data acquisition/recording for all four payloads during the mission, as well as to operate and test the airborne equipment aboard vehicles A10.903, A13.030, and A13.031 during the prelaunch phase of the countdown. Twenty-three man days of this total effort were provided as support under this contract.

The desired conditions were achieved on 7 March 1981 and the salvo launched in the following sequence:

Vehicle	Launch	Experiment
A13.030	0809 UT	Electrostatic Analyzer & Photometer Array
A13.020	0810 UT	Mass Spectrometer
A13.031	0830 UT	Electrostatic Analyzer & UV Spectrometer
A10.903	0838 UT	Falling Sphere/Electron Density Experiments

Data was received from all payloads and the mission judged successful. Results have been reported in greater detail under the preceding AFGL contract.

The next following support activity at PFRR was a continuing project under the Solar Proton Event (SPE) program. This series called for a group of correlated instruments aboard a number of rockets to be taken to the launch site, tested and prepared for launch as a salvo, and then stored there (with the ground station left set for launch), and kept in a state of readiness, awaiting an alert when proper conditions developed for the desired SPE. The ground station complex included a Minitracker for data acquisition, plus the requisite receivers, discriminators, strip-chart recorders for display, and magnetic tape recording for flight. A total of four payloads were prepared for flight in the several attempts at completion of the series in 1981 and 1982. The payload support system for one of the mass spectrometer payloads had been originally constructed by OSU under preceding contract F19628-78-C-0033 and later refurbished for this series; the other three airborne telemetry systems were provided by a separate agency. Although various attempts were made to launch the complete salvo in four different schedule slots (spring and fall periods, when conditions were regarded as optimum), and much of the equipment was left at the PFRR site between schedules, the desired event never occurred at a time when the salvo could be launched. One rocket, A10.901-2, was launched as a diagnostic round (to verify that the program was viable) at 2130 UT on 26 October 1981, but there was no solar proton event under way at the time of launch. The program was continued through several successive reschedules in attempts to complete the salvo of A10.903-1, -3, -4, and related payload A14.021-2 under the desired geophysical conditions. In

October of 1982, after six trips with a two-man crew and the total expenditure of 134 man days of travel, the program was cancelled and the remaining equipment returned to the base laboratory in Oklahoma.

Similar support services were supplied in conjunction with the launch from the PFRR facility of two Field Widened Interferometer payloads. The ground station supplied for this support again included the Minitracker for data acquisition and a similar related complex of terminal equipment, this time with some PCM support GSE added for the two-link signal to be received, and once again required a two-man support crew for tests and prelaunch activities, followed by a substantial delay in the field while awaiting the desired geophysical conditions for each launch. The FWIF instrument was first launched aboard Sergeant vehicle A30.175 at 1204 UT on 7 November 1981 with anticipated performance from the vehicle, which reached an apogee of 138 Km. Telemetry and radar performance was good, but the data from the instrument was not in accord with expectations, and apparently the instrument did not function properly.

A reflight was later scheduled aboard vehicle A30.276 in the spring of 1983. This mission was scheduled in conjunction with the ELIAS project, which carried a large and complex payload aboard the Talos Castor vehicle A51.971, and the same OSU personnel and much of the same equipment was used in both support missions, which overlapped in time and, because of instrument difficulties and priorities with regard to launch windows and facilities, created a number of delays and changeovers in station set-up. TRADAT trajectory coverage was also supplied, and a compound 3-receiver station developed to permit support of either mission with the required discriminators, PCM decoders, displays, and multichannel magnetic tape recorder. After an elapsed time in the field of almost three months and several crew changes, the second FWIF instrument was launched aboard A30.276 at 0906 UT on 13 April 1983, during the desired auroral conditions. Vehicle performance was again nominal, with essentially the same apogee as on the first flight. Good data was obtained and the instrument functioned as expected this time; recovery was successfully accomplished later. Actual support effort for the FWIF missions is difficult to evaluate, because of shared field time with support for the ELIAS project; based upon those delays due to weather or equipment problems when ELIAS was not scheduled, it is classed as having required a total of 118 man days.

The ELIAS project referred to above accounted for much of the support effort in the January-March period of 1983, but was similarly difficult to define because of the overlap and schedule turnarounds which were imposed either by technical difficulties with the complex payloads, or were due to adverse weather conditions. On many

occasions the countdown proceeded for both payloads while awaiting the desired event. However, based upon time not attributed to exclusive support of the FWIF payload, the total effort devoted to this project was 128 man days. The ground station requirements for this vehicle were complex, requiring the use of the Minitracker II and an associated TRADAT V system for ranging, with three associated S-band receivers for the three-link telemetry signal from the payload, One link carried a straight PCM reply and the two other links were used for multichannel FM/FM signals; the ranging was carried back from the vehicle on IRIG channel 18 within the FM complex of one of these latter links. Although the primary ranging coverage was via the NASA station at PFRR, the OSU station was scheduled as back-up coverage. Payload checks for this payload began on 26 January 1983 and, although partially successful, disclosed an intermittent problem with the PCM link which appeared to be related to the timing sequence for the ACS system. Tests continued through 5 February, at which time a decision was made to postpone further checks while portions of the PCM system were returned to the vendor for test and repair. Tests were resumed later in February and attempts to reschedule made in the period of 9 through 22 February, after which operations were temporarily suspended while trying to launch the FWIF payload. Technical problems were next encountered with the latter payload and, by 9 March, both payloads were again in readiness for launch and a new plan for shared countdown developed in which both payloads remained in readiness, with count possible on either, depending upon weather and the geophysical conditions available. This situation continued until 18 March, when the ELIAS payload was successfully launched aboard A51.971 at 0630 UT on 18 March 1983. A good flight ensued, with apogee reported at 300 Km and usable data obtained, although the PCM signal was noisier than desired. A turnaround was made the same day and count resumed for the FWIF payload until 22 March, when the window closed; all equipment was then put in storage with the crew returning to their home bases.

The next mission in which support services were supplied to AFGL for a payload which did not otherwise involve OSU participation was actually a NASA flight of a Nike/Black Brant VB rocket from the range at Fort Churchill, Manitoba, Canada. This payload for NASA involved a number of ejectable probes and other instruments retained aboard the main vehicle; seven different carriers in the P-band region were used for the NASA experiments. AFGL added a special TV camera in the main payload, transmitting a wide-band signal on a carrier frequency of 2215.5 MHz. Because the ground receiving station at Ft. Churchill was not equipped to receive this signal in S-band, OSU provided a special ground station for acquisition and recording of the video signal from the TV camera. A full Minitracker station with multicoupler and three receivers was supplied, with

associated terminal equipment including both AFGL and OSU equipment.

The preliminary integration tests for this payload were performed at the GSFC facility in Maryland, and required one man for a single day in the fall of 1981. Launch support at the Canadian site required two men with a total additional effort of 55 man days in January of 1982. After a considerable delay due to misplaced equipment shipments and bad weather at the Arctic launch site, the Minitracker was set up and all equipment placed in readiness; prelaunch tests commenced on 13 January and were satisfactorily completed on 20 January, after which the payload was placed on the launcher and held in readiness for proper launch conditions. The desired auroral activity was obtained under conditions which permitted full countdown and the payload launched aboard vehicle number 27.045UE at 0352 UT on 26 January 1982. Although an apogee of 239 Km was reported and the trajectory passed through the auroral arc on both up and down legs of the flight, low signal strength was received from the TV transmitter and no data was observed on either the TV camera or the associated photometer aboard the NASA partion of the payload.

3.4.3 Brazilian Ionospheric Measurement Experiment Support Work.

The BIME project was provided major support during this contract period. This project involved coordination travel to the Brazilian launch site in Natal, which required the services of one man for twelve days in discussion of the general plans for support of the mission and logistic requirements to be encountered. A second coordination trip to AFGL was devoted to discussions of the technical requirements for both the airborne and ground station equipment to be provided in support of this mission, which was to include launch of four rocket payloads in a coordinated series of measurements. Two pairs of rockets were planned in two different salvos; in each one rocket, a Black Brant VIII, was to make measurements of the ionosphere and deliberately induce disturbances in the ionosphere by detonation of charge at the proper altitude, after which a second Sonda III rocket would be launched to measure the disturbed ionosphere.

OSU was assigned the responsibility for overall construction and build-up of the Black Brant VIII payloads, while Northeastern University was to do the Sonda III portions of the experiment. The Black Brant payloads were quite complex, and a photograph of the completed payload section is shown as Figure 4.

The overall BIME payload, constructed at OSU, involved design, construction, modification and acceptance testing of a number of items, both mechanical and electronic, for inclusion in these payloads. The mechanical items included the modification of the Nike-Black Brant Igniter Housing, design and fabrication of the

Payload Support System housing, internal structure, and aft boom cover release mechanism, both housing and cover assemblies, cover deployment mechanism, and ion sensor mounting structure. Special electronic items included a specially developed PCM encoder, PAM commutator, command decoder, airborne power and pyrotechnic control circuitry, and GSE control consoles. All documentation pertaining to these designs were assigned X42FXXX drawing sequence numbers and are available upon request.

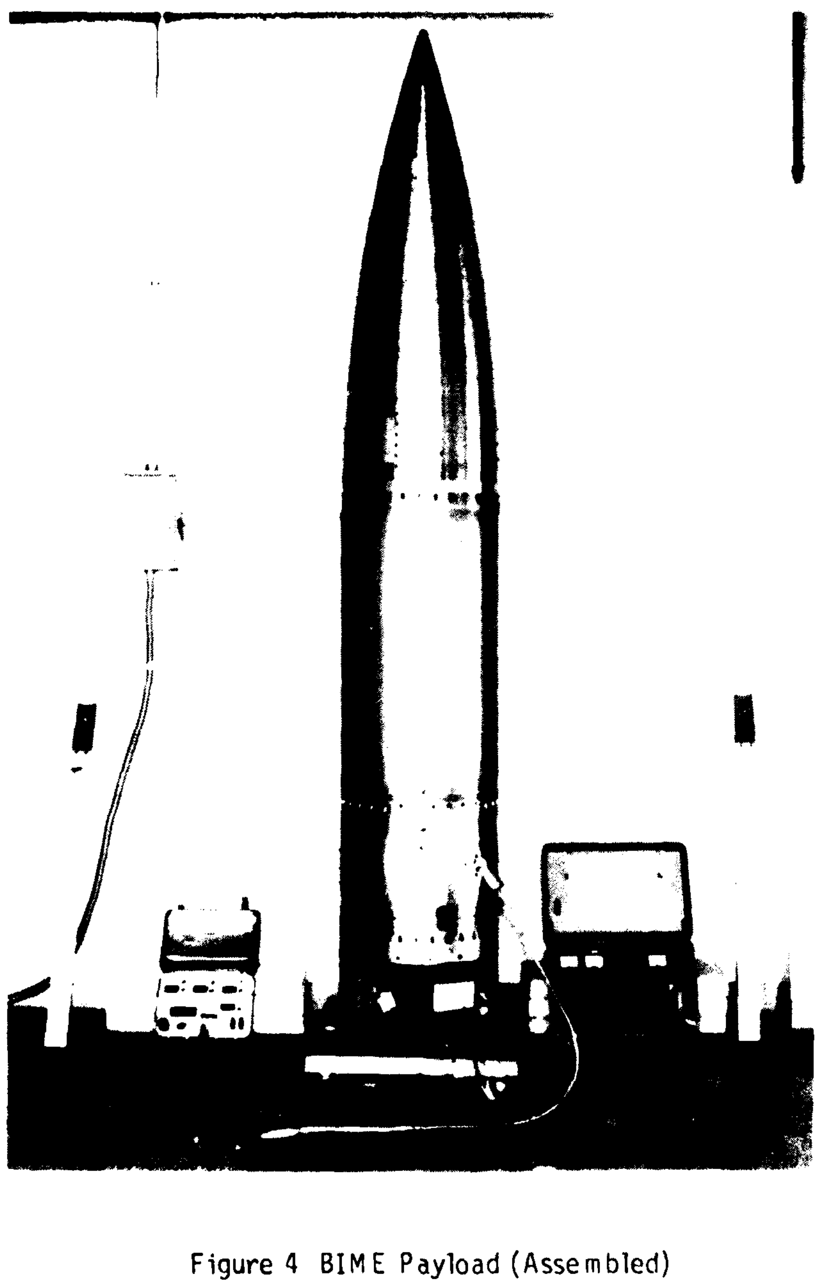


Figure 4 BIME Payload (Assembled)

Each BIME payload system was made up of four major subsystems; the instrumentation

subsystem consisting of the Pulsed Plasma Probe, provided by Naval Research Laboratory, and Ion Sensor Probe, provided by AFGL; the telemetry subsystem, consisting of PCM encoder, FM subcarrier multiplexers, PAM commutator, S-band telemetry transmitter and antenna, provided by OSU; the command, control, and ranging subsystem, consisting of ranging receiver, command decoder, mechanical timers, and relays, also provided by OSU; and the explosive payload section consisting of 15Ø lbs. of ammonium nitrate, fuel oil, booster chain, and electro-explosive devices, provided by Franklin Research Institute.

Modification of the Nike-Black Brant Igniter Housing included removal of all command destruct hardware, despin hardware, and addition of wiring to provide firing current to the PSS section. The ranging and command receiver and receiving antennas were mounted in the existing holes in the housing.

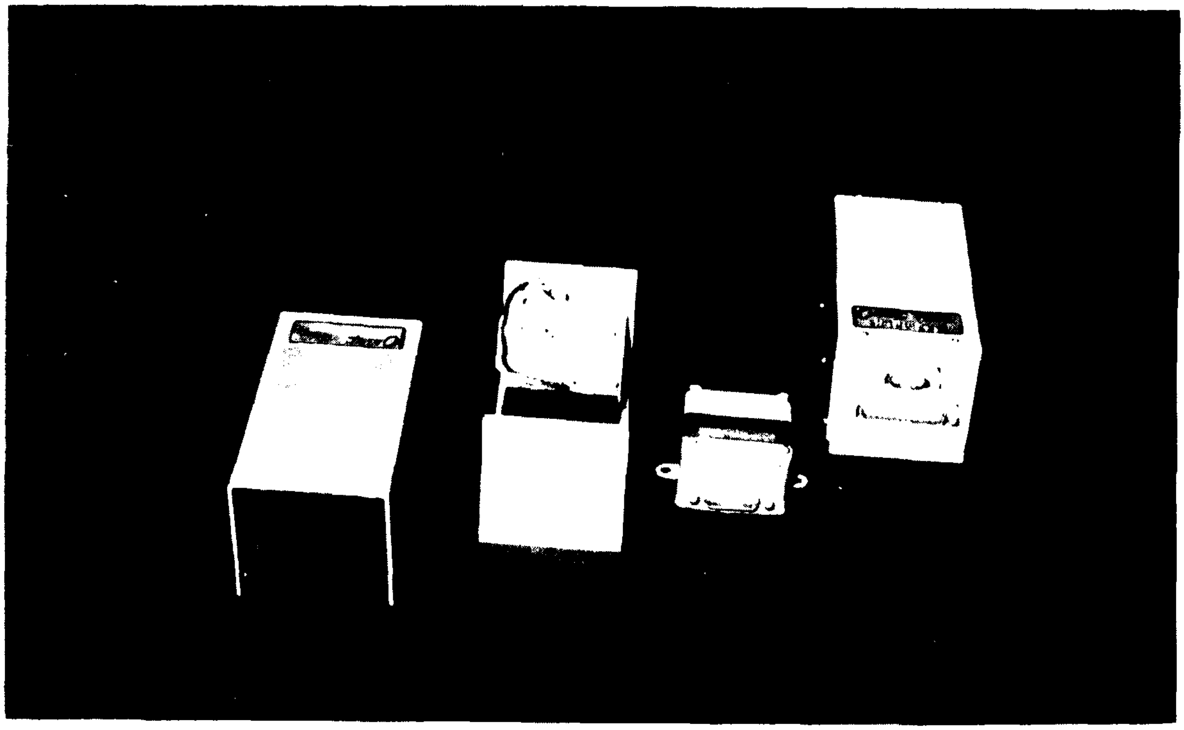


Figure 5 BIME PCM Encoder

The PSS section contained the telemetry subsystem and Pulsed Plasma Probe electronics box, with the deployable probes mounted on plates inside the housing, and protruding through the skin. Also housed in this section was the command, control, and ranging subsystem. The specially designed PCM encoder (Figure 5), provided by OSU, produced clock signals for the Pulsed Plasma Probe in order to synchronize the operation of the

probe electronics with the encoders sampling times and provided analog inputs for the probe data and various housekeeping and performance data. The NRZ-S PCM code at 28.8 kibits/sec was formatted as follows:

Word length	9 bits
Minor Frame length	8 words
Major Frame length	16 Minor Frames
Subcomm Sample rate	25 S/sec
Minor Frame rate	4ØØ/sec
Input Voltage	Ø-5 volts

The output of the encoder modulated an IRIG G VCO in the FM multiplexer. Also shown in Figure 5 is the PAM commutator. This commutator provided additional housekeeping information and it's output modulated an IRIG 9 VCO in the FM multiplexer. Other data passsed through the telemetry system via the FM multiplexer was the AFGL Ion Sensor data on an IRIG 12 VCO, and the Igniter Housing prime squib current monitor data on an IRIG 13 VCO. Along with the telemetry and instrumentation housed in the PSS section was the command, control, and ranging subsystem. This subsystem provided for ground control of the payload during testing and prelaunch, as well as ranging and uplink command during flight. The control system, when connected to the GSE payload console via the umbilical cable, allowed operation of the payload from either external power supply through the umbilicals, or on the internal battery supply within the PSS section. The control system was also required to initiate boom deployment, electrical arming of the explosive section, and in the event of failure of the command system, detonation of the explosive section during flight. The system built to fulfill these requirements consisted of a pair of 3 switch 3ØØ second Raymond mechanical timers modified by OSU, and associated relays controlling power provided by the igniter housing. By taking the power from the igniter housing "down stream" from the baroswitch and arming plug circuit an additional margin of safety was attained. In order for detonation of the explosive system to occur several conditions would have to occur: 1) all electrical and mechanical arming completed; 2) an altitude of 20,000 ft must be attained by the vehicle; 3) a minimum flight time of 2Ø seconds elasped. The heart of the ranging and control subsystem was the OSU designed Tradat V Command Decoder. This was a modified version of the command decoder flown on PBOT and described in the previous Final Report. Modification of this decoder consisted of circuit simplification due to the relaxed requirements of 2 commands of 4 bits each. A description of the general operation of this component can be found in AFGL-TR-81-0203. Physically the

Command Decoder looks identical to the PCM encoder shown in Figure 5. The Command Decoder performed three basic functions in the BIME payload: 1) Provided signal conditioning of the PCM range code from the ranging receiver; 2) Provided the switch closures required to detonate the explosive section upon receipt of the proper uplink command; 3) Provided command confirmation for preflight testing by inserting the command into down-linked range code. The conditioned data output from the Command Decoder modulated an IRIG 18 VCO in the FM multiplexer, and, as the rest of the data, was telemetered. In addition to above systems, a radar transponder was also included in the PSS section. The transponder was a Vega C-band type which was field-modified for single-pulse operation. The conversion to single-pulse operation was made to eliminate differences in requirements between BIME and a previously scheduled Ariane program.

On the forward end of the PSS section was mounted the ANFO canister (explosive section) provided by Franklin Research Institute through which passed two 3/4 inch conduits. These conduits provided a passageway for electrical cables between the ogive section, where the electrical arming connectors and the Ion Sensors were located, and the PSS section. Also located on the forward end of the ANFO canister was the mechanical arming mechanism for the explosive booster chain.

The OSU Electronics Lab also provided modifications to the ogive to provide mounting of the Ion Sensor detector plates and access to both mechanical and electrical arming mechanisms. Also provided within the ogive was the boom cover release mechanism. This mechanism consisted of a steel cable which passed through two Holex 5800 guillotine cable cutters, and was attached to each of the boom covers. When squibs were fired, the cable was cut and a spring under each cover drove the forward end of the cover away from the ogive. At an angle of about 45 degrees, the covers would release from the aft pivot point and, due to the roll of the vehicle, fly outward.

Upon completion of the construction phase of this program a complete test and evaluation phase was undertaken. These tests, performed at AFGL, consisted of mechanical, electrical and environmental qualification and evaluation. After completing these tests both payloads were prepared for shipment to the launch site.

The lab also provided extensive ground support for the BIME program. The overall requirements of this program necessitated the fielding of two complete tracking, trajectory, command, and data acquisition ground stations. In addition to the normal recording and display equipment, connection to other special ground support equipment, such as a special purpose decommutator, and computer system was required. Because of the simplified airborne command decoder flown, a simplified command coder was

designed for inclusion in the ground station. The Command Coder, shown in Figure 6, operated in an identical fashion to the decoder described in AFGL-TR-81-0203 with the exception of the total number of command words available. The previously described coder was capable of four eight-bit commands, as opposed to the coder provided for BIME which required only a simple 8 bit word.

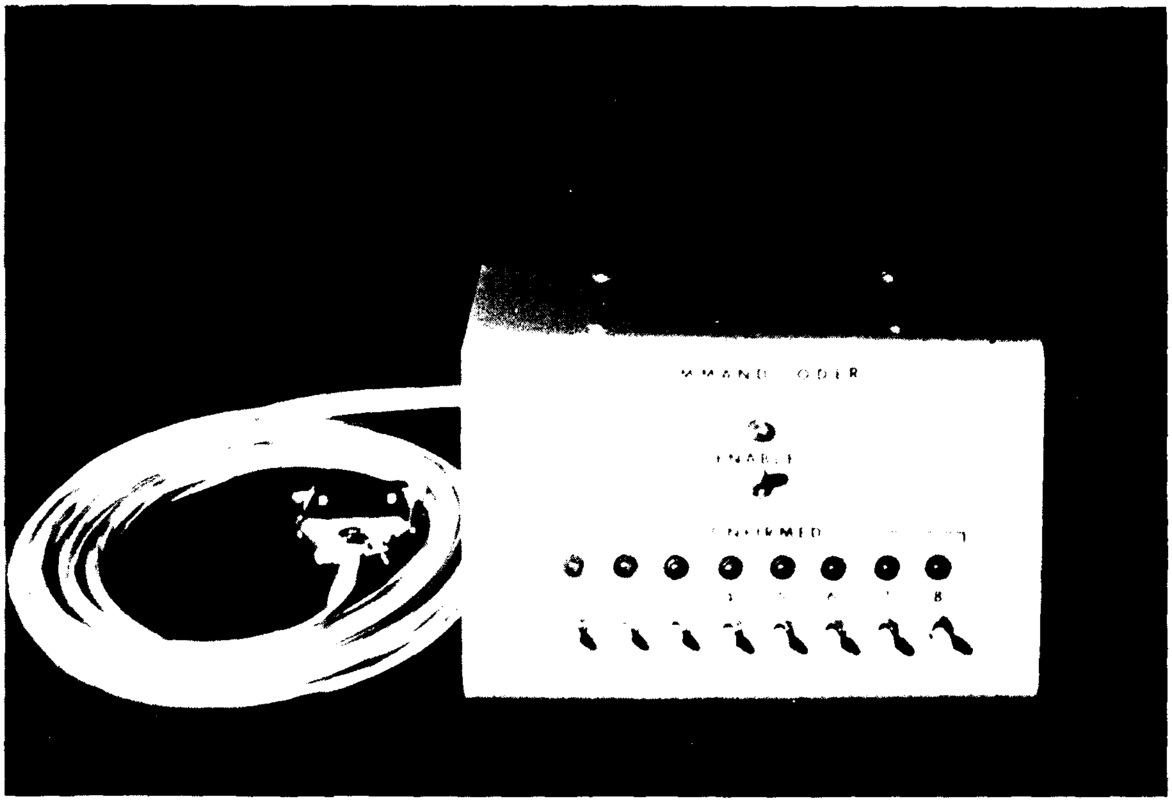


Figure 6 Command Coder

Due to the unknown quality of the timing provided by the range, a NBS satellite synchronized clock was provided by OSU. The Kinemetrics model 468-DC is a self contained radio receiver-digital clock that is automatically set by the down-link signal from the GOES geostationary satellite. This unit provides IRIG B with an ultimate accuracy of 1 ms.

Field support for the BIME program commenced on August 17 and the first vehicles were launched September 8. A19.124-1 was launched at 21:42:01 GMT. Detonation by radio-command occured at T+3 min. 23 sec. at an altitude of 322.81 Km. A2.123-1 was launched at 21:52:01 GMT attaining an apogee of 522.55 Km at 21:58:16. Both vehicles

performed nominally and all instrumentation functioned normally. The second pair of vehicles were launched September 13. A19.124-2 was launched at 21:Ø5:Ø1 GMT and was detonated at an altitude of 333.5 Km at T+ 3 min and 31 sec. A2Ø.123-2 was launched at 21:11:Ø2 GMT reaching an apogee of 548.49 Km. at T + 6 min. and 22 sec. The Sonda III failed to take wind correction and Mass Spectrometer sensor cover failed to deploy. Field support of the BIME program was concluded September 2Ø with return of all lab personnel to Stillwater.

3.4.4 POLAR IONOSPHERIC IRREGULARITIES EXPERIMENT (PIIE)

The purpose of this project was to measure the Ionosphere Parameters during polar cap scintillation events. The analysis of these measurements would help to determine the plasma physics responsible for lengthening polar scintillations, and would allow the development of a predictive capacity for communications systems which propogate through this region. Simultaneous measurements for the experiment were to be performed by the AFGL KC-135 Airborne Ionosphere Observatory, the incoherent scatter radar at Sondre Stromfjord, Greenland, and by ground-based optical and polarimeter measurement sites.

The project consisted of one instrumented, high altitude rocket, and one chemical release payload. The Oklahoma State University Electronics Laboratory was responsible for the design and construction of the telemetry and support electronics of the chemical release payload, which will be described in this section.

Major components in the payload support system (PSS) for the PIIE chemical payload include the following; C-band transponder, 10 watt S-band transmitter, ranging receiver, PCM encoder, signal conditioner, primary and backup electronic timers, command decoder, relay box, power distribution board, 2.3 Amp hour (AH) battery for telemetry, 1.2 AH battery for the transponders, roll and spin magnetometers, and accelerometer. An ion sensor and electronics box provided by AFGL were located in the base of the ogive. Three thermistors were located on the skin of the ogive, with a fourth thermistor on the transmitter. Bent-valentine antennas were mounted on the skin of the PSS for the C-band transponder, as well as an S-band stripline antenna installed for telemetry.

The Nike-Black Brant igniter housing, provided by Bristol Aerospace was modified by removing all command destruct and despin hardware and the addition of the chemical release pyro firing current wiring to the PSS section. Ranging receiver stub antennas were mounted in existing holes in the housing.

The chemical canister, which contained seven chemical containers, was provided by Franklin Research Institute. The chemical canister was installed between the ogive and the PSS.

All data inputs to the encoder are multiplexed and converted to a digital PCM NRZ-level, eight-bit code. The format for the 32 Kbit PCM encoder (OSU Drawing No D42PBØ1) consists of eight (8) minor frame words with thirty two (32) minor frames per major frame. A standard Barker code frame sync is found in minor frame word zero with the minor frame I.D. in word one. Words two, three, and four contain subframe housekeeping data while words five, six, and seven contain squib current monitors and ion sensor data. The encoder has two outputs, the first being a hardline which is sent via a line driver through the Payload Support System (PSS) umbilical line to the control console. The second output is sent to the signal conditioner. There the PCM NRZ-L signal is mixed with the output of a 70K Hz (Ch 18) VCO which contains information from the 550MHz ranging receiver. This combined PCM/FM signal is then fed to the 10 watt S-band transmitter which operates at 2251.5 MHz.

Primary and backup electronic timers developed by OSU (OSU Drawing No. C42PTØ1) are used onboard to control the chemical release events. The timer is Eprom programmable and may include up to eight separate functions with a maximum time frame of 512 seconds. The timer's first function is to arm the relay box to the chemical release firing circuits. Seven other functions follow which fire the canister squibs at pre-determined times. The backup timer is redundant, engaging the same set of relays four seconds behind the primary timer. The timers may be started and reset manually through the control console on either internal or external power. Upon launch, the timers are started when the umbilical line is pulled out, provided the system is on internal power.

Due to a requirement from the Danish Defense Ministry, a command system was added to release the chemicals in the air in the event of no second stage ignition. A manually operated command control box located at the ground station initiates a coded PCM signal which is sent in the bit stream to the uplink TRADAT ranging transmitter. The video out of the 550 MHz ranging receiver onboard the payload is fed to the command decoder (OSU Drawing No C42PLØ1) and to the 70K Hz (Ch18) VCO. Once the decoder is enabled, an independent set of relays are engaged to fire the chemical canisters. Two commands are used, with the first command engaging the arming relay and the first three relays in the timer sequence. The second command engages the last four relays in the sequence. Command confirmation from the decoder is inserted in the down link range code. Confirmation is decoded and displayed on the command control box. The command

system is identical to the one used on the BIME project.

The PIIE payload support system incorporates a redundant safety system to prevent premature firing of the chemical release canisters. A pair of baro switches in the igniter housing will prevent the command function from being armed below 10,000 feet . A second pair of baro switches prevent the timers from firing the canisters below 20,000 feet. The baro switches are in series with HR-1 batteries located in the igniter housing . In addition, a safe/arm connector located in the payload must have the arm plug installed for continuity to the firing circuits.

The payload control console was used to operate the PSS through the umbilicial lines. The control console provided manual start and reset of the onboard timers, switched the payload between internal and external power, and monitored battery voltages as well as telemetry and transponder current.

Telemetry from the payload support system is received through the S-band receiver at 2251.5 MHz. The composite PCM/FM video from the receiver is then fed both to the TRADAT ranging discriminator for ranging data, and to a 40K Hz low pass filter. The filter passes the 32K bit PCM code which is fed to a bit sync and decommutator. Best signal lock was obtained by converting the NRZ-L code to a BiØ-level code in the bit sync.

The Electronics Laboratory provided a ground station for operational checks of the payload and two man months of field support for PIIE in Sondre Stromfjord, Greenland. Although the instrumented round was fired , the chemical round was not launched due to unfavorable conditions.

3.4.4.1 Programmable Flight Timer

The PIIE program was initially to be identical to the BIME program, with the exception of the elimination of the NRL Pulse Plasma Probe and associated boom cover mechanism. Some time after the initial design and procurement phase of the program had been completed modifications of the mission objectives were made and the ANFO system was replaced with a seven canister chemical release system. The original design called for the use of Raymond Engineering mechanical timers for initiation of the explosive system. Considering the extended times and number of functions required, coupled with the expense and lead time in procuring the mechanical timers, a decision was made to develop an electronic flight timer. Taking into consideration the requirements of the PIIE program and the desire to keep the design as simple, yet as flexible as possible, a programmable timer designed around an electrically programmable read only memory was developed.

The electronic flight timer, depicted in OSU drawing C42PTØ1, was designed around an Intersil IM6654IJG 512x8 EPROM. This device was chosen because of its flight proven use in other designs, and programming equipment availability. The basic circuitry consists of a clock and divider chain which produces one pulse per second, a binary counter which counts the pulse per second clocks and generates addresses from Ø to 511, the EPROM which contains the timing program and utilizies the addressing from the binary counter to generate the timed functions on the data lines, the high current relay drivers and relays, and the timer control circuitry.

The EPROM contains 512 locations, each location containing 8 bits (DØ-D7). When an address is applied to the address bus and a latch pulse is supplied to the EPROM the data contained in that address location is transferred to the data bus of the device, and remains on the bus until the address is changed and the next latch pulse is received. In this application the address bus is connected to the output of a binary counter, which increments one address each second, and each data line is connected to an individual relay driver circuit. Now let us assume that we want to start a particular operation on the payload at 1ØØ seconds. Let us further assume that this operation is controlled by application of 28 vdc, and that function Ø (DØ) of the timer is connected to the circuitry being controlled. All data contained in the EPROM addresses Ø thru 99 would be zeros (ØØØØØØØØ). At address 1ØØ thru 1Ø9 the following bit pattern would be present on the data bus; ØØØØØØØ1. If no other function were to occur the remainder of the locations would also contain zeros.

At this point it should be apparent that each data bit (function) can be programmed to be on (1) or off (Ø) for any time from Ø to 511 seconds. In actual operation the timer starts upon the opening of the low reset line on the timer. When this line is opened by either the opening of the console test switch or the removal of the umbilical, the resets on the divider chain and address counter are lifted and the timer begins to operate. Operation is ended when the address counter reaches 512, inhibiting further pulses from reaching the counter input.

The PIIE program timer system consists of a dual timer system with both timers housed in a single package 4 3/32" x 3 1/8 x 2 11/32" and weighing less than one pound. The timers were thermal cycled by both OSU and AFGL, and a complete shock and vibration to Black Brant acceptance levels was performed at AFGL. The Timer is shown in Figure 7.

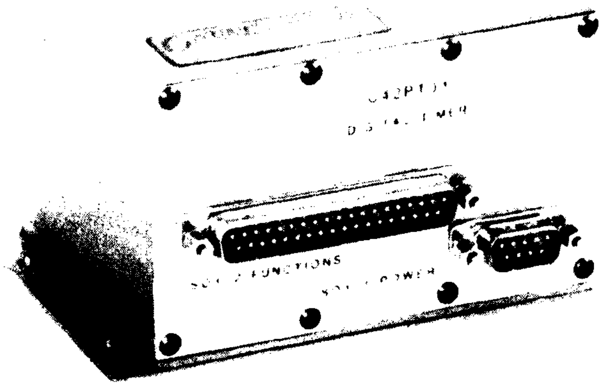


Figure 7 Programmable Flight Timer

3.4.5 Harp

The HARP program is a cooperative effort between the Air Force and CTA/IAE of Brazil. The vehicle, a SONDA IV, is a two stage, pedestal-launched rocket provided by Brazil. The first stage is stabilized and controlled with a secondary injection system using an annular ring and valve system to inject freon for attitude control based on a stable platform. A small solid propellant rocket motor is attached to each of the four fins on the first stage. Two of the motors are for roll rate control and two for retro propulsion after staging. The separation system is an air bag system provided as part of the vehicle.

There are two telemetry systems on board, one of which is the Brazilian system, and one provided by OSU. The Brazilian telemetry has a general task of monitoring all rocket performance functions. The OSU telemetry will monitor operation of the planned recovery and flotation system along with required monitors for a cryogenic system called PSFC (Proof of Super Fluid Concept).

The skin section containing the dewar for the PSFC and the skin of the recovery-floation system are wrapped with heat resistant material for protection from over-heating during re-entry.

Two drop-tests of the recovery-floation system were successfully completed in March, 1985, and the planned launch date for the Sonda IV is November,1985.

The following paragraphs describe the function of various parts of the OSU telemetry system.

3.4.5.1 Encoder

Part of the telemetry portion of the Harp payload was the design and construction of a twelve bit PCM encoder. The format for the encoder was as described below:

77 Kilobits BiØ/L Code
12 Bits/Word
8 Words/Minor Frame
2 64 Word long subframes (Word 2 & 3 of Minor Frame)
SFID in word 1 of minor frame
Minor frame sample rate of 800/sec.
Subcom Word sample rate of 12/sec.

Of primary importance in the design of the encoder was the ability to resolve temperature related data down to approximately 1 mv. The 12 bit system provides resolution down to 1.22 mv to meet this requirement. In addition, the encoder contains a precision temperature controlled voltage reference whose output is fed to the first word of each subframe to provide measurement of absolute encoder accuracy.

The encoder (Ref Dwg. D42HC01) consists of a crystal controlled clock whose basic frequency is 1.232 MHz. This clock is divided by 16 to derive the 77 KHz clock for the encoder. Additionally this clock is divided by 12 to obtain the word clock and again by 8 to obtain the minor frame reset. Each minor frame reset is then counted down still futher to obtain the subframe address information and subframe reset after 64 subframes have elapsed. This minor frame count is counted in groups of 8 to provide enables to the subcom multiplexers which select the data. There is a total of 126 analog inputs available on the two subcoms (word 0 of each subcom is hard wired to the precision reference internal to the encoder). Words 4,5,6,& 7 of the minor frame are available to sample data which requires higher sample rates than that achieved by the subcom. The subcom data and the minor frame data is multiplexed and fed in the proper time share sequence to an Analogic 14 bit A/D converter short cycled to 12 bits. A 14 bit A/D converter was selected due to previous analysis of the inherent real accuracy of the 12 bit vs the 14 bit converters. The output of the A/D converter is latched and clocked out as a serial NRZ/L code which is then converted to a BiØ/L code in the final stage prior to

the output buffer.

Temperature tests were performed on the encoder with verification of 1 bit accuracy (1.22 mv). Accuracy of the precision reference source was better than 1 bit over the temperature test.

3.4.5.2 Timers

To provide timing for various payload functions a prime and backup electronic timer was built. These timers were improved versions of the EPROM programmable timers originally developed in support of project PIIE. Improvements consisted of the use of 2048x8 EPROMS, allowing timing of 2047 seconds, use of MIL PC board construction rather than wirewrap, and the option of using either positive true or negative true logic for programming the functions in the EPROM.

The timers (Ref Dwg D42HT01) consists of a crystal controlled 40.96 KHz basic clock counted down to provide a 1 PPS clock. This clock is then counted by a MC74HC4040 binary counter whose outputs are used as address lines to a TM2516JS EPROM. Upon completion of the count to 2048 seconds the timer is disabled and timing stops until such time as the timer is reset. Reset of the timer is accomplished by a switch closure. In actual use this closure is provided by either a liftoff switch on the rocket or by pins on the umbilical. Timer start is upon opening of this reset line.

The EPROM is programmed by computer thru the use of a GTEK EPROM programmer or optionally through manual programming with an auxillary programmer. As noted previously, this programming can be either positive true of negative true logic. This was done because the EPROM when fully erased contains all FF's.(11111111 in binary) and in some cases, especially manual reprogramming, it might be shorter to program 0's for on times and leave the other "FF" portions to provide the off function in inverted logic operation. Each of the eight bits on the output of the EPROM is fed to the inputs of either a 74LS240 (for inverted logic) or a 74LS244 (for non inverted logic). Outputs from this device then go to a ULN2003A (2 req'd) which in turn control 8 Teledyne J432D-26 relays which provide both normally closed and normally open control functions.

In addition to the control functions, the relays also provide relay status information in the form of a 5v signal indicative of closed or open relay contacts. This timer information can be monitored through telemetry in order to provide diagnoistic aids for data analysis related to timer controlled functions.

Both the prime and backup timer are housed in the same enclosure and utilize totally independent power supplies. This concept provides the option of prime/backup 8 function

timer operation or single 16 function capability in one unit.

One of the added advantages of this type of timer is in control of functions which require multiple on/off times. In the past, these involved multiple notch cams which had to be precision machined and were difficult to set. This timer design could conceivably have as many as 1024 one second long on/off times (ie 1 second on and 1 second off) per function, all with crystal controlled accuracy.

The program written to supplement the programming of the EPROM through the GETK EPROM programmer was written in BASIC computer language using a Radio Shack Color Computer. It was designed to be very user friendly and sends information to the EPROM programmer via the serial RS-232 printer interface in the computer. Additional information on the software and it's usage is available on request.

3.4.5.3 Signal Conditioner

The HARP telemetry is composed of two systems interfaced as one; the main encoder operating at 77K Hz and the PCM ranging operating at 1.9 K Hz. The airborne portion of this interfacing consists of a signal conditioner which performs several functions. First, it filters the 77K Hz PCM through a 6 pole 20K Hz high pass filter to minimize low frequency components. This filtered PCM is fed through a buffer and on to the mixer. Second, it combines the buffered 77K Hz PCM and the 1.9 K Hz PCM from the ranging receiver video out and provides the ability to set the deviation of each. Finally, the combined signals are buffered in a final stage where total transmitter deviation can be adjusted. This method allows both the PCM encoder data and ranging data to be telemetered on the same transmitter without the need for a VCO.

In addition to the airborne signal conditioner, and additional 6 pole lowpass filter is utilized in the ground station setup to filter out the 77K Hz PCM before the video is sent to the ranging system. This filter has a 6K Hz 3db rolloff point and effectively prevents the 77K Hz data from causing interference with the ranging.

3.4.6 LAIRTS

Requirements for the LAIRTS program included design and breadboard of a system to assemble in storage the asynchronous digital data from an array of 128 x 128 pixels and their associated A/D systems and format these data into a synchronous bit stream for magnetic tape recording. Inserted into this bit stream were sync words and housekeeping data. Two scan speeds were required and this system was successfully breadboarded and is being reported as Scientific Report No 1 on a follow-on contract F19628-85-C-0006.

3.4.7 BERT II Feasibility Study

During the contract, OSU Electronics Laboratory was also involved in study, definition and evaluation of the technology required to fly a neutral beam accelerator as a sounding rocket payload. Interest in this program came from two particular groups. The first group showing interest in such a program were physicists interested in upper atmospheric research, the second group's interest was application of these techniques related to the Space Defense Initiative.

The major effort in preparation of the various study reports produced by the lab was travel to the several meetings to discuss and investigate the various approaches to this project that were being considered. Travel included two trips, the first of which two men visited three sites in a one week period. The first site visited was the Westinghouse Defense Electronics Center near Baltimore, Maryland, where we discussed the possibility of using a solid state R.F. power amplifier in a sounding rocket payload. The second site visited on this trip was AFGL where we were briefed on the objectives and scientific background, reviewed the feasibility study schedule, and discussed vehicle capabilities and results of the Westinghouse visit, with Air Force , Space Vector, and SIE personnel. The final site visited during this trip was to Los Alamos National Laboratories, Los Alamos, N.M.. During this visit we were briefed by the Accelerator Technology Group about basic requirements of neutral beam accelerators, and visited their labs to see an accelerator of a similiar energy level in operation. After completion of the first trip, and some additional study, the Electronics Lab submitted the first report to AFGL. From initial information and investigations it seemed that it would be technologically possible to accomplish the goals of this project, although many questions remain unanswered at this time. Futher study of these questions was recommended.

After additional study of the program requirements a second trip to AFGL and Westinghouse Defense Electronics Center was made. This trip, supported by one man for a ten day period, involved OSU personnel giving a review of the Westinghouse R.F. power amplifier including its operation and power requirements, development of a "strawman" payload, and observation of the Westinghouse power amplifiers operation into a hi-Q cavity similiar to the cavity being considered for flight. Upon conclusion of this trip a series of reports were submitted to AFGL including a letter report assessing the technical feasibility of this program, a simplified description of the Westinghouse Power Amplifier, recommendations concerning instrumentation and telemetry, and budgetary estimates.

4.0 TRACKER AND TRAJECTORY WORK

4.1 Minitracker and Tradat Modifications and Development

The modifications to the Minitracker include a modification of the pedestal and replacement of the four foot reflector with a six foot reflector as described in Section 3.2.5 of this report. A photograph of this system is shown in Figure 8.

Figure 8 Modified Minitracker

In addition, two helix antennas were developed for ranging, and an up-converter to provide capabilities of operating at frequencies other than S-band was breadboarded and tested.

An alternate method of PCM ranging was tested, and a plotter controlled by a microcomputer were developed and tested.

4.1.1 Up Converter Design

The Electronics Laboratory has over the years developed and built several Minitracker Systems. One of the RF feeds used with these trackers is equipped with a broadband monopulse converter covering a frequency range of 1435 MHz to 2300 MHz. To take full advantage of the capabilities of the Minitracker, a receiver covering these same frequencies is desirable. Due to the considerable expense of purchasing several tuning units for the existing receivers an alternative method of conversion of these receivers by providing an outboard up-converter was considered. An intial test of the performance of the preamplifier outside of its designed passband was performed and was found to operate well as low as 1650 MHz. Although the preamplifiers operation would not be acceptable at lower frequencies these initial test results were encouraging. A 1680 MHz receiver was then improvised using a signal generator, double-balanced ring mixer, and an available S-band telemetry receiver. The 1680 MHz receiver was connected to the Minitracker system and tested successfully. A "breadboard" local oscillator was then constructed using a crystal oscillator and multiplier chain technique. This circuitry was then substituted for the signal generator as the L.O. A narrow bandpass filter was also provided to eliminate harmonics of the L.O. which could enter the mixer and produce undesireable "birdies" in the S-band receiver. Although fair results were obtained using the multiplier chain L.O. with the narrow bandpass filter, it is felt that by using a fundamental frequency oscillator such as a DRSO (dielectric resonator stabilized oscillator) or the multiplier chain oscillator would greatly improve the upconverters performance.

The addition of the upconverter for both 1680 MHz and the 1435-1535 MHz bands would be an inexpensive approach to increase the Minitrackers capabilities, and it is strongly recommended that continued effort be expended in this area to enhance the capability of the Minitracker and its role in this and other Air Force programs.

4.1.2 Uplink antenna development & construction.

To improve the operation of the Tradat/Minitracker combined system it was necessary to develop an uplink transmitter antenna for Tradat which could be pointed by the

Minitracker. It was also evident from tests conducted with the systems that a smaller and lighter uplink antenna than that used with the Tratel trackers was necessary.

Helix antennas for both 550MHz and 430MHz were developed. In an effort to keep the gain of the antenna as high as possible, while still maintaining good circular polarization, tests were conducted on antennas with different spacing and coil diameter. In addition, the antennas were tuned to provide the lowest VSWR. The final antenna dimensions were documented in dwgs # C95MA13 and C95MA14 and in actual tests provided performance similar to that of the earlier larger antennas.

The advantages of the new antennas were; 1) Light weight and easily handled by the Minitracker without need for changing the tracker counterbalance assembly. 2) Smaller diameter groundplane thereby permitting mounting of the antenna in front of the S-band feed on the tracker without unacceptable shadowing of the dish. 3) Maximum efficency during usage since the antenna is pointed by the tracker. 4) Simplified shipping due to decreased size.

4.1.3 TRAP System Development

A system to acquire ranging data through a PCM telemetry system was developed. The system uses the regular TRADAT PCM ranging uplink which is received by a ranging receiver in the airborne unit. The PCM telemetry system is utilized for the down link. The ranging frame sync pattern is detected in the airborne unit to start a BCD interval counter. The time base for this counter converts the time to kilometers as is done in the ground based TRADAT system. The counter is then stopped by a selected bit in the PCM format. The BCD output is entered into a word (or words) of the PCM format to record the delay incurred between the detected ranging frame sync pattern and the selected bit in the telemetry format. The selected bit then furnishes the stop pulse to the ground station interval counter through a normal PCM decommutator. The recorded delay is then subtracted by computer from the ground station interval counter output to give the slant range.

This system was flown as a piggyback experiment on two balloon launches in conjunction with a BAMM launch at Chico, CA. A recovered PCM encoder and command through ranging system which was flown on A18.805 (PBOT) at the White Sands Missile Range was modified to impliment the airborne unit. It was flown together with the standard TRADAT V system to compare the slant range readings. During the flights the range readings drifted apart from 150 to 300 meters with TRADAT V having the greater reading. It is thought that this may be due to temperature change during the long balloon

flights.

Two antennas were built for each frequency. Both the 550 and 430 MHz were used with the Minitracker/Tradat system in support of project BIME in Brazil. Operation was considered excellent.

4.1.4 Ranging System Digital Plotter

Real time and post flight printouts of trajectory information have been available from the Tradat system in digital form from its conception. It is often desirable however to have this information shown in graphic form such as altitude vs ground range or azimuth vs ground range. Previously this information has been unavailable in most instances. To fill this need, a special interface was developed and built which allows printouts on an X-Y plotter of the information from the Tradat/Minitracker system.

The plotting system was built using an inexpensive Radio Shack Color Computer, a Watanabe Model WX4675 multipen X-Y plotter, a special computer/TRADAT system interface box, and associated software programs. Two different printouts are available in either realtime or playback, altitude vs ground range or ground range vs direction.

The heart of the special plotting system is the interface box and associated programming which allows Tradat data to be translated to information usable by the computer and subsequently by the plotter. The interface box (ref dwg C99XY01) was built using a R6532-13 RIOT chip, a TMS2708JL EPROM, BCD to decimal decoders, and a TMM2016A 2Kx8 static RAM. RS-232 data from Tradat is sent to the interface box where it is converted to corresponding parallel data and stored in RAM awaiting the data request from the computer. This conversion of data is handled by a machine language program (PLOTAS15) stored in EPROM in the unit. The program converts the Tradat BCD data to Hex data for use by the computer.

The data is fed from the interface box to the Color Computer via the Rom-Pack port on the computer. A BASIC program, ALTGRG or GRDNE15, is used to determine the correct format and timing to print this information as an X-Y plot. The BASIC program also contains the information necessary to draw the graph with the selected parameters. These parameters are selectable through questions which require keyboard entries during the initial setup procedure. During the initial setup routine the information related to the particular launch (i.e. date, name, location, etc.) is also printed on the graph in the upper right hand corner. Both the X and Y axis are labeled on the graph and reference grid lines are drawn. Once the setup routine has been completed and all corresponding graph information drawn, the computer begins looking for data from TRADAT.

The plotting programs may be used in either the normal or smoothed data mode with TRADAT. The printouts are multicolor permanent type scaled to show the best display of data.

5.0 Other Research and Development Projects

Other projects which were studied during this contract were high-density digital recording and applications of microprocessors for control, along with various updates to the KIM -4. Use of a microcomputer for control of a digital plotter is described in section 4.1.4 of this report.

5.1 HDDR Studies and Tests

The purpose of these studies was to improve the capability for recording and playback of high bit rate PCM telemetry. Two approaches to the study were taken. The first was to try to evaluate the capability of auxiliary devices for reduction of bit error rates. The second approach was to investigate conversion of serial PCM to a parallel form and use of the tape system as a parallel recorder.

The first approach included a demonstration of a commercially available unit, an Ampex M2EDU. The conclusion reached after comparison of its use to conventional recording was that there was no improvement in the rate at which data could be recorded by use of the unit. The unit was judged to be a convience, but not to be a real advantage.

The second approach was to use the data clock and data to enter into registers to provide parallel outputs to the tape recorder. It proved to be a problem at high bit rates due to jitter and resultant time misalignment of the parallel bits. Once again, this technique was judged to be too difficult for use with the present systems.

5.2 Computer Development and Usage

Several improvements in the KIM-4 system were made to permit auto test routines to be applied. They include an auxiliary card and clock, hardware changes and additions, use of a multiplexer box, a digital voltage programmer, and a temperature sensor. These changes are incorporated in OSU drawing Series X92KXXX. Some of these updates are included in Ref No 10 and Reference No 17. (Note: Reference No 17, Technical report No 4 submitted in manuscript form, IRIG FORMAT "B" Decoder).

6.0 GROUND SUPPORT EQUIPMENT

As needs have indicated, update, changes, and new equipment have been added to improve the quality of launch support. The PCM terminal equipment has become increasingly complex and more versatile, general ground support has been improved and

special purpose items have been provided as required.

6.1. PCM Terminal Equipment

The PCM terminal equipment provided includes the application of the DAC-20 processor (Ref 11.) improvement in resolution of the 8-channel DACS, provision of high-resolution single DAC displays, and modification of the DSI7112 word selector to operate with either OSU or EMR decoders.

6.1.1 DAC -20 Development

THe DAC-20 described in Scientific Report No 3 (Ref No 11) was developed in order to provide data display as decoded from high bit-rate PCM systems. It represented a first attempt to use microprocessor control for data sorting. This task has been accomplished in the past, using hardware systems alone. The unit described in the Scientific Report has been updated to provide the full 20 analog outputs to 12-bit resolution. It consists of a data-processor system for timing as well as data entry from a front-panel keyboard. For a detailed description of the operation and design of the unit, the reader is referred to Scientific Report No 3 and OSU drawing series X90PEXX. The unit is shown in Figure No 9 of this report.

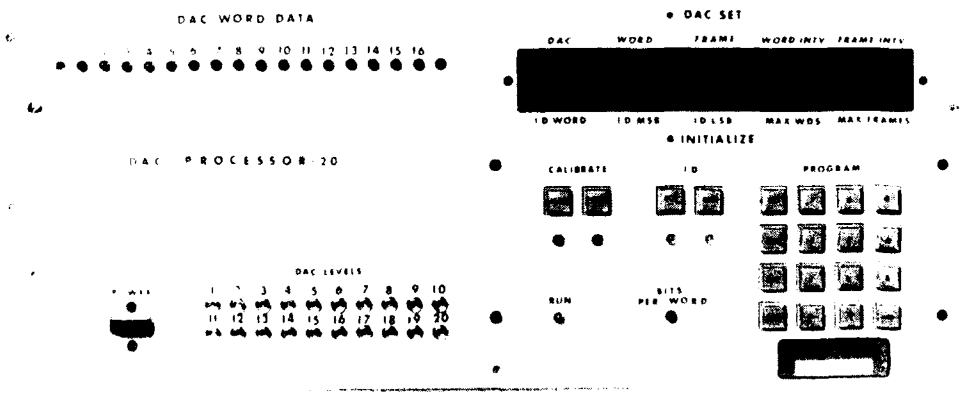


Figure 9 Dac 20

6.1.2 Eight Channel DACS

A total of three 8-channel DACS were constructed in the previous AFGL contract and during the present contract. For a complete description of their operation, please refer to Reference No 3.

During the course of this contract, two revisions to these units were made. In the prototype and the second unit, the capability of recognizing a sub-frame synchronization pattern was accomplished by insertion of a single wire-wrap IC card which was wired such that it was committed to a specific PCM encoder. All units were revised to include a selectable pattern capability, along with a modification which selected the number of bits/word to be converted. The drawings describing these modifications are C90DB02, Revision B, and C90DB03, Revision A.

6.1.3 High Resolution DAC Peripherals

On several occasions, the necessity to display high resolution data to a project scientist during instrument cooling arose and this requirement prompted the use of high-resolution (12 to 16 bit) DAC's for measurement of background noise. The systems were packaged in small interface boxes and were used to observe any one of several sensors by switching the word to be observed from the front panel of a PCM decoder. By the use of DIP switches, the total number of bits of resolution was selectable. These high-resolution DAC's were used in the laboratory during instrument testing as well as during field support efforts prior to launch for real-time display during flight.

6.1.4 DSI 7112 Word Selector and EMR 710-02

A DSI 7112 Word Selector in use by AFGL was modified to be compatibile with existing decoder systems. This word Selector requires that a minor frame sync pulse, a major frame sync pulse, and a word clock occur simultaneously. A simple modification to the system permits direct use of the EMR 710 with this system. The word clock is run through an inverter to give the correct polarity and time relationships among the three pulse times for correct operation. A connector on the rear panel of the EMR 710 was re-wired to be pin compatible with OSU decoders. An interface box was installed at the rear of the word selector to accomodate the OSU decoders. A drawing, B99ER12, shows the contents of the box and the functions.

A second change was added to the Word Selector while modifications were being tested. The D-A converted data had a frequency limitation when high-sample rates were used. Capacitor CN06, with a value of 150 pf, was replaced with a 5 pf capacitor, and much higher frequency response was observed. This is shown in the technical manual, DSI

drawing No 015145.

6.2 Miscellaneous Items of Ground Support Equipment

Several items of general utility to AFGL support services were constructed in the course of this contract period. In addition to the PCM terminal equipment reported above and minor items of convenience to the overall program, this area of activity also provided a compact discriminator rack, a Countdown/Countup Clock which can also supply locally generated timing signals, and a multiple output constant current battery charger.

6.2.1 The Tricom Model 442 Minirack has been briefly described in section 3.4.1 of this report, in conjunction with the falling sphere program and MAP/WINE support activities. Circuit details are as shown in OSU drawing B99PR21A. It was originally developed to supply the special needs of one specific project, but has been of benefit to the general program by providing a flexible adjunct to the standard 8-Channel Tricom discriminator racks which were built for AFGL use earlier (Ref. 2, section 8.7). The general features of the electrical design were retained and a number of features added to improve the utility of the item by providing built-in calibration features and switching circuits which, in effect, eliminated the requirement for a patch panel and more complex ground station cabling. At the same time, the mechanical design was modified so as to permit a much smaller unit, which could be shipped in the "miscellaneous" GSE box without requiring a special fitted shipping container normally used for the original design. The main chassis roughly duplicates the compartment at the left side of the earlier 442 rack, but the bulky fixed compartments which were used to accommodate eight plug-in discriminators in the earlier design have been replaced with hinged back plane and front support arms which can be folded and stored within the wiring compartment for shipment. A change to lightweight sheet metal construction in place of the rigid plate structure of the original design resulted in a more compact and much lighter unit, only 2.5 x 3.5 x 17 inches in size and weighing 4.5 pounds when folded for shipment. The rack can hold a maximum of four standard Tricom Model 442 discriminators and can be operated as a stand alone system for simple support missions such as the sphere program, or used in conjunction with one of the standard racks to extend the number of channels available for more complex analog telemetry applications.

The features of front panel BNC monitor jacks for Band Pass Filter output and Discriminator output were retained, with a two-pole four-position rotary switch to permit these jacks to be connected to any of the four discriminators. This feature permits the "BPF" monitor to be cabled directly to a counter and the "Disc" monitor to go to a monitor oscilloscope, permitting station checks without cable changes by use of

the selector switch. All four discriminator outputs were again brought out through individual 1 Kilohm galvanometer deflection adjustments to a side-mounted row of Litteljax 12B connectors which mate with the standard OSU galvanometer harnesses, but this time the adjustments were provided through multiturn potentiometers which are mounted on the front panel instead of the side, which makes recorder set-up more convenient. Outputs from discriminators A and D are also available on BNC jacks at full level, independent of the adjustments. (This was done for convenience in the sphere support program; in this application, A was assigned for range timing, B and C were for the normal Channel 16 and 18 analog channels, and D allocated for the sphere PCM signal on Channel H.) The output from discriminator D is taken to one side of a test switch and a separate BNC "Simulator" input connector to the opposite side; the common arm then is wired to a "PCM Decoder" connector which may be cabled directly to the sphere PCM decoder and thus permit changeover from the normal Channel H Video PCM signal fom the sphere to a simulated PCM input, without changes in station cabling. If the A discriminator is not in use, a local signal such as the OSU time code may be connected to the rack at the "Time" BNC connector for Channel A and the galvanometer deflection adjustment and galvo jack are available for independent use. The feature of Tape Speed Compensation is also retained, with the BNC "TSC" connector wired to pin 2 of all four discriminators, as was done in the standard rack. A "RCVR Video" connector is hard-wired to pin 1 of discriminators B through D; pin 1 of discriminator A can be switched to either this same bus, or connected to a separate "Disc A" input connection on the rear by a rear-mounted switch on the Minirack for use as a demultiplex discriminator, when desired.

A built-in five channel calibration oscillator has been provided. A standard OSU model B35AV11 5-position mount with adjustable resistance mixed output is mounted within the chassis in such a way as to permit access to a maximum of five standard air-borne subcarrier oscillators. The mixed output is wired through an "Op/Cal" switch to the discriminator input bus, and is also available on a separate "Cal Osc" BNC connector for use with other equipment without change in station cabling. An internal power supply provides the required DC operating voltage for all subcarrier oscillators from AC line voltage and also, through an adjustable down regulator, provides the DC calibration voltages of zero, 2.50, and 5.00 volts needed for reference frequencies at lower band edge, band center, and upper band edge from each subcarrier oscillator. Since these step-voltages are frequently of use for other purposes, they are also brought to a pair of "Cal Step" banana jacks on the side through the "Op/Cal" switch step selector. This same selector switch also disables the calibrator in the "Op" mode to reduce interference, and

illuminates a pair of LED indicators labelled "Op" (green) or "Cal" (red) on the front panel to remind the operator of the selected mode of operation. The +30 volt DC bus for the calibrator is also available on a switched pair of "+30v Out" jacks for external use. In sphere support missions, this switched power is used to operate the field spare decoder, whose output is connected to the "Simulator" input to provide PCM test signals without the necessity for changes in the station cabling.

6.2.2 Countdown Clock:

In order to perform many of the tests required for launch of a particular payload, it is necessary to provide a visual display of time referenced to some initial start time. This can be in the form of a countdown to T-0 and continuation as a plus count or possibly a count starting at T-0 and continuing as a plus count. In any event, it is necessary to provide this timing to meet the requirements related to support of each launch program.

To fulfill the timing requirement it was necessary to procure or construct a countdown clock which would be capable of meeting many unique situations. After searching for a suitable commercially available clock it was considered more practical to build a countdown clock which was tailored to the specfic needs of the programs.

The functions deemed necessary were: 1) Display hours, minutes, and seconds with large (1 inch) LED display. 2) Presettable hours, minutes, and seconds count in either plus or minus count. 3) Start and stop with or without reset of displayed time. 4) Time display of minutes, seconds, and hundredths of seconds for higher accuracy in timing certain events. 5) Ability to start or stop time externally by switch closure. 6) Outputs of .1Hz, 1Hz, 10Hz, and 1000Hz pulse as related to seconds of time. 6) BCD time code output identical to existing Datum time code generator/readers to insure compatability with TRADAT and other current systems. 7) Unit self contained and yet light weight. 8) Output time code suitable for recording on tape or paper records with capability of identifying a particular event by a shift in level of this time code. 9) Display test option to verify all segments of each numeric display. 10) Reset of time to zero at any time, whether clock is running or stopped.

The following text is a description of the circuity used in the countdown clock built to provide this support. (Ref Dwg # D99CL01 & C99CL02).

The basic clock reference for the countdown clock is derived from a 2.56 MHz crystal oscillator. This clock is counted down by a 12 stage ripple counter short cycled to divide by 28 (256). This division followed by a division by 10 in a decade counter provides the 1000/sec. pulses which are outputted to the rear panel BNC connector. Additional

decade counters result in outputs of 100/sec, 10/sec, 1/sec and .1/sec pulses which also output on BNC's to the rear panel. Each of these counters is reset to zero by logic during R/S to zero, preset up count, preset down count, and stop such that the continuation of the countdown is referenced to the reset.

External start and stop of the clock by switch closure is done through individual one-shots such that even if the external start switch remains closed the stop switch will still initiate a stop function. The outputs of the start/stop one-shots are used in parallel with the start/stop switches on the front panel of the clock to set or reset a "D" flip-flop which enables or disables the timing pulses going to the actual countdown clock time display circuitry.

The clock frequency going to the actual display can be selected as 1/sec or 100/sec by a switch on the rear panel of the clock. This allows display of time displayed as hours, minutes, seconds, or as minutes, seconds, and hundredths of seconds. These pulses are used to drive a series of presettable counters. In the normal hours, minutes, seconds mode the first two counters count units seconds and tens of seconds with the tens of seconds limited to a maximum of 5 (ie, max second count before shift to the next minute is 59). In the minutes, seconds, hundredths of seconds mode each counter can count up to 9 resulting in .99 seconds as the maximum reading before transfer to the next second. The second two counters count minutes or seconds up to 59 depending on the timing mode selected. The fifth and sixth counters count to 9 resulting in count of hours or minutes to 99 depending on the mode selected. Maximum time for normal mode of operation is therefore ± 99h59m59s and in the optional mode ± 99m99.99s.

The outputs from the counters just described are fed to a group of six BCD to 7 segment latch decoder drivers, further through 6 resistor DIP IC's and subsequently out to the associated segments of the six LED seven segment displays.

The up/down select line for the presettable counters is also fed through a buffer and transistor driver to illuminate a ± sign at the far left of the display to indicate whether the indicated time is in the minus count (countdown) or plus count (countup). Automatic transfer to plus count is performed at the zero time crossover point and timing continues in the count up mode.

Presetting a particular count is accomplished by "jamming" a BCD count into the "jam" inputs of each of the presettable up/down counters. The thumbwheel switches on the front panel of the countdown clock provide the means of presetting the count anywhere within the limits of the system. In order to preset a count, the desired time is dialed up

on the thumbwheel switches on the front panel of the clock and either the preset up count or preset down count button on the front panel is depressed. The display will then indicate the selected count time with a plus or minus displayed indicating the selection of count up or count down. Since this action also resets all the counters associated with timing to zero it can be used to resynchronize the clock with other timing sources even in the running mode.

The actual display is provided by high visibility LED 1.02" tall seven segment displays. These displays provide visibility to over 40 feet for persons with average eyesight.

The countdown clock including power supply is housed in a 4"H x 10" W x7" D high impact resistant plastic housing and is shown in Figure 10.

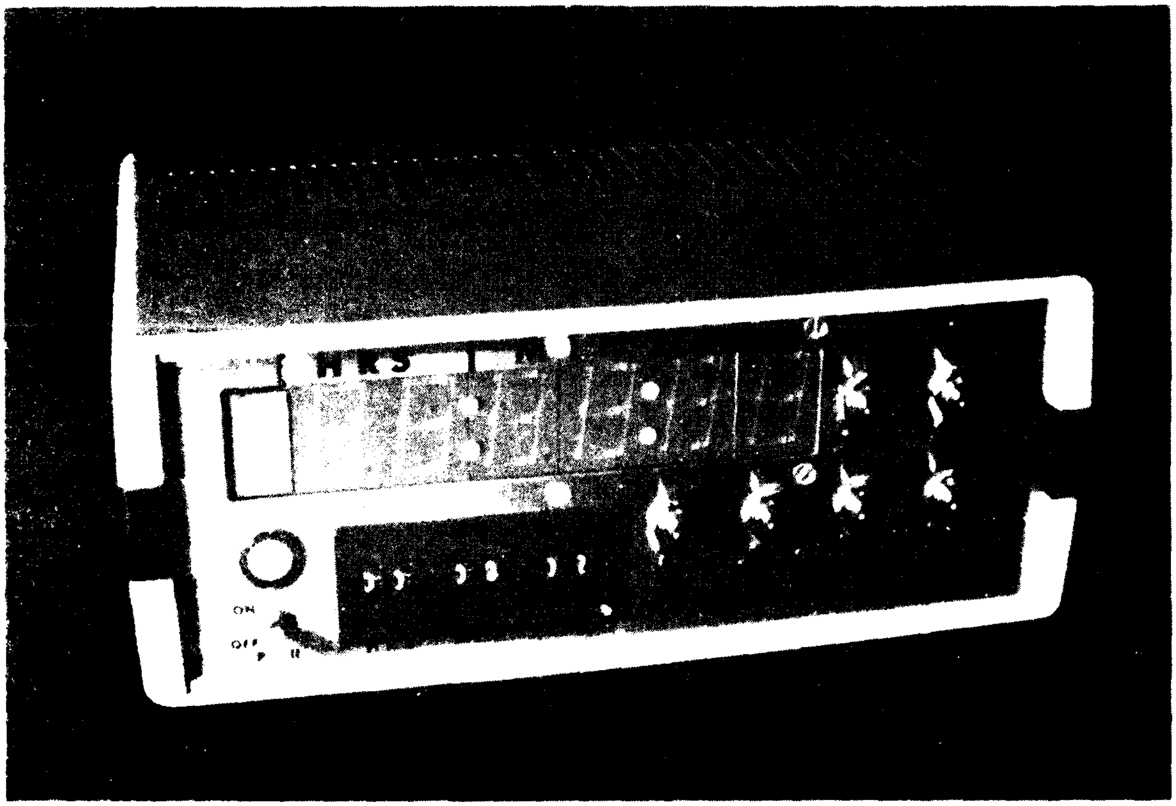


Figure 10 Countdown Clock

The power supply for the clock is run from 115VAC and provides +12,-12, ands +5v for all the logic and display. CMOS technology was utilized throughout the units design thereby keeping power requirements to a minimum. Power consumed by the LED display portion (major power consumption of the clock) is less than 10 watts.

6.2.3 Constant Current Battery Charger

Many telemetry systems contain separate battery packs to power such things as transmitters, beacons, pyrotechnics, and experiments. Most of these battery packs are of the NICAD type and are therefore rechargeable. Further, it is often desirable to charge and discharge these batteries several times to qualify them and also "form" the cells to maximum life. This process in the past required several power supplies, one for each battery being charged. Also, with the use of several different types of batteries it is desirable to be able to charge the batteries at different currents based on manufacture's data. In order to meet this need, a multiple constant current charger was built which allows a single power supply to charge six batteries at the same time, each being charged at a preset constant current. See Figure 11.

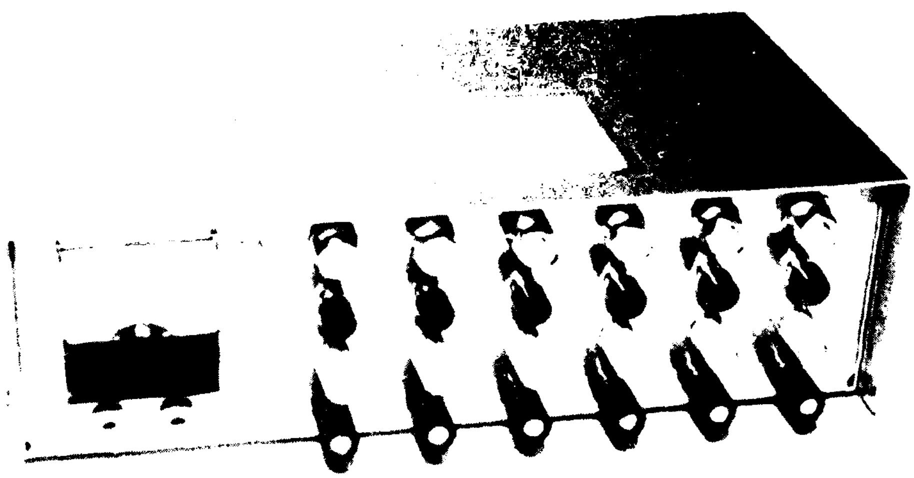


Figure 11

The constant current multiple battery charger (Dwg# C99CC03) was built to charge up to six batteries using a single power supply whose rating is such that it will provide the voltage (up to 40v) and total current requirements (500 ma x 6 = 3 amp max) of the batteries to be charged. Each section of the charger is built around a LM317KC variable voltage regulator operating as an adjustable constant current device. Each unit has adjustable current charge rates of from 50 to 500 ma. The individual currents are monitored on a 0-500 ma meter on the front of the charger. Diodes in series with each output line prevent battery discharge in the event of power loss or power supply failure.

This charger allows batteries of different terminal voltage to be charged at the same time, the only requirement being that the supply be set high enough to charge the battery with the highest terminal voltage.

6.3 Special Purpose Ground Support Equipment

Several items were designed and constructed in the course of this contract for use as special purpose ground support equipment. This GSE was developed and built for direct application to programs underway at the time. Two items were for special usage in the falling sphere program: the switchable 8-channel sphere decoder, and the special DART Thermosonde Data Converter. Two additional items were built for the MSMP and BMP projects: the Az/El error signal coder and display set used for X-band tracker calibration in the TEM-3 program, and the SVC air bearing PCM telemetry system provided for qualification testing in all BMP projects. All have been briefly described in preceding sections of this report, in conjunction with the support services supplied to the individual projects.

6.3.1 Eight-Channel Switchable Sphere Decoder

The special PCM decoder constructed for use under the falling sphere project was the subject of a special report prepared under this contract (Ref. 14). It was developed as a piece of test apparatus which could be used at OSU for local testing of C40BE02 encoders, and also included features to permit use as a compact and convenient GSE item for field support services. The original "All Words" sphere decoder (Ref. 3, section 8.4) was built with 16 decoded analog outputs, 15 of which used 8-bit DAC units to decode and convert data words 1 through 15 into analog outputs to drive an associated set of strip-chart recorders. The sixteenth channel was switchable to any desired word, drove a digital light display to show the binary form of the selected word, and also derived a 10-bit resolution analog representation of the selected word for use both as a panel monitor

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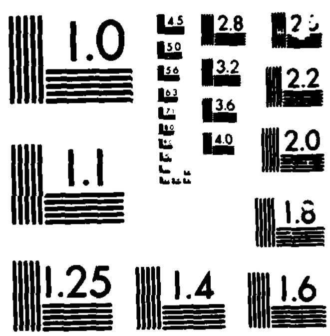
UNCLASSIFIED F/G 14/2 NL


1.0
2.8
3.2
3.6
4.0
2.2
2.0
1.1
1.8
1.25
1.4
1.6

and as a galvanometer drive to an external recorder. This unit was delivered to AFGL and has normally been kept there, which made testing of new decoders at OSU inconvenient unless the unit was shipped to the local facility each time tests were required. The newer model C90TD12 unit was designed as a smaller and somewhat simplified version, with added features which made the equipment compatible with the standard computer-controlled system which is used at OSU for qualification testing of flight hardware. In the field experience gained with the earlier "All Words" version of the decoder, a disadvantage was noted in the necessity for changing cable connections from the individual word outputs to the strip chart recorders when different formats were desired, and because the individual outputs differed in level, a new calibration and pen set-up was needed for each change. The switchable version provided six outputs which could be cabled to the six inputs of a recorder and set initially to the desired positions and deflections, then switched at will to any desired words without changing cabling or amplifier adjustments. Two more outputs from permanently wired channels for word 13 (Nutation) and word 14 (Voltage Monitor) data were also provided, since these signals are normally used for data correlation in data displays during playback operations, which expanded the capability to eight analog output signals. Since the feature of full 10-bit resolution and digital display was needed in set-up and testing of the encoders, one switchable channel was provided with the 10-bit DAC circuitry and both analog and digital display capability. Because all encoders are built and qualified with the subcommutated housekeeping capability in word 15, one other switchable channel was provided with the capability of decoding the subcommutation for frames 0 through 7 in word 15; this same section permitted decoding main frame words 8 through 15, had an analog monitor meter, permitted the output to be scaled to represent either the normal bipolar $\pm$ 5 volt data span or only the 0 to + 5 volt span used in the subcommutated housekeeping mode, and was provided with a second panel display of the decoded data.

Circuitry was similar to that used earlier, and relied upon the Bi-phase Level PCM data string for automatic bit synchronization without the added complexity of a phase lock loop clock; the regenerated bit clock signal was brought out as a monitor for counter checks of bit rate. The data conditioner was of the usual simple biassed Exclusive Or gate form, and automatically reinverted word zero in alternate frames so that a simple frame synchronization detector could be used. Internal bit, word, and frame counters were synchronized by detected minor and major frame synch patterns in the incoming data string. These counters drove decoders; six panel-mounted hexadecimal switches then permitted selection of the decoded word or frame signals to latch the desired data

into "shift and store" registers, where the parallel binary data lines could be converted to analog form by the DAC for each channel. Converted analog signals were then fed through operational amplifier drivers with adjustable output controls to the eight galvanometer connectors on the rear panel. The output data was available on both BNC connectors and Litteljax 12B connectors which were compatible with the standard OSU galvanometer harnesses. Additional monitor outputs were provided on the front panel for the two channels which drove the 10-bit lamp display and subcommutated data, in order that an external digital voltmeter might be used for accurate data readout. Outputs were also provided for monitor of the bit and word clocks, minor and major frame sync, and the selected word sync from the "A" channel of the decoder.

Switching circuitry in the input to the data conditioner permitted normal or inverted data operation (which permitted use with direct PCM, or from detected data from the hybrid PCM/FM/FM telemetry with discriminators of either sense). The same circuit also switched decoder input to a built-in digital calibrator signal which provided 0, 50, or 100 % calibration of all output signals at will. For convenience to the operator, screwdriver adjustments for zero and full-scale points on the two analog displays and level adjustment of all eight outputs were front panel mounted. To permit oscilloscope checks of the PCM data, two additional panel-mounted BNC connectors were provided, one in parallel with the Bi-phase Level input PCM and the other on the "A" channel shift register output, so that the selected data could be observed in NRZ-L form.

For interface directly to the OSU computer-controlled qualification test set-up, an independent portion of the decoder is driven by the conditioned serial PCM data and synchronized by the word clock and minor frame sync signals. Each word of the incoming data is successively latched into a 10-bit data latch by the word clock signal, and the ten parallel data lines are fed to the proper pins of a standard 50-pin interface connector for connection to the computer. At the same time, word clock pulses are counted by a two-digit BCD counter which is reset by minor frame sync. The BCD word address so generated is also latched by the word clock and fed to the proper pins on the same interface connector, for use by the computer. Additional pins provide timing to the computer with word, minor frame, and major frame sync signals, and also provide the required DC reference voltages.

Two additional but unrelated circuits are provided within the decoder as a convenience for field use. A two-stage operational amplifier, with separate input and output connections and gain control, has been added for use as a microphone preamplifier. This

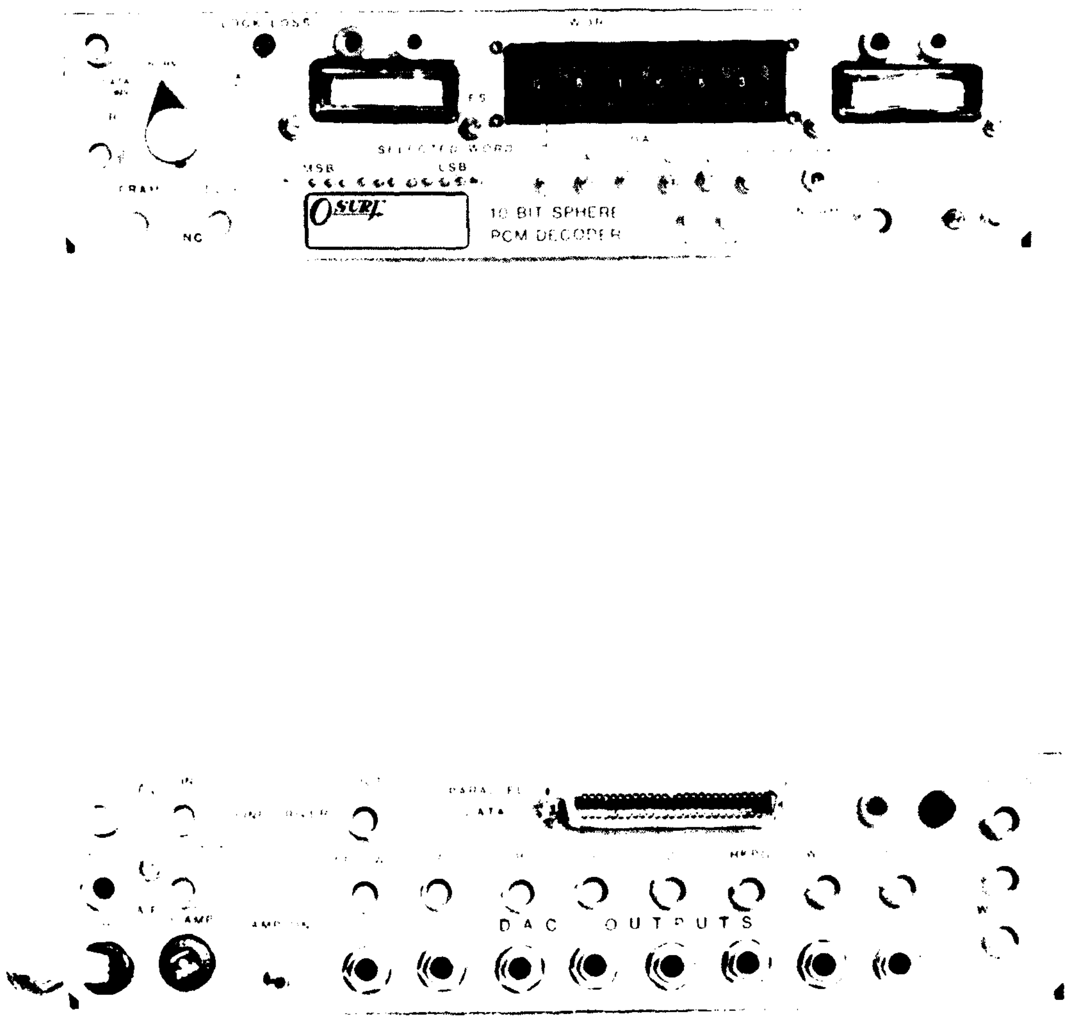


Figure 12 Eight Channel Switchable Sphere Decoder

provides the capability of conditioning voice data from a local microphone for use as modulation to the associated FM/FM station multiplex when desired. A second subcircuit provides a line driver, again with independent input and output connectors and output level adjustment, so that additional equipment is not required if station location is such that remote lines are required to peripheral equipment. Power for these circuits is also taken from the internal power supply, which provides all necessary operating voltages from standard 115 volt 50/60 Hz AC input. The unit is very compact and, with dimensions of only 3 x 8 x 12 inches, can be carried in a briefcase. Use of the system is described in Reference 14. See Figure 12.

6.3.2 One additional special GSE item was developed and three units built for use in the MAP/WINE campaign (Ref. 16). This equipment was designed for use with data received from SDC Model PWN-11D DART thermosondes, which were used to detect the ambient temperature in the upper atmosphere. These DART sondes use a tiny thermistor to sense temperature, and transmit data to the ground on a carrier frequency of 1680 MHz by a string of 100 microsecond wide pulses; the number of pulses per second is proportional to the temperature. The temperature data is periodically replaced during flight by a reference frequency generated within the sonde as an aid to calibration. The OSU model C42DD01 Data Converter was designed to provide an analog output voltage derived from these received data pulses, proportional to the measured temperature, for use in real time display of the data received from the sonde and also for drive to a slow-speed strip chart recorder. The data converter also includes built-in calibration features for set up of the associated recorder, and internal timing, which can be synchronized with slow speed range timing signals.

The data converter accepts the output from the receiver used to detect the transmission from the sonde. Because the pulse data from the sonde may be either positive or negative, the data conditioner was provided with a panel adjustment for bias, to permit operation with signals of either sense over a wide range of amplitude. The output from the data conditioner is used to trigger a pulse-stretching multivibrator, which converts the narrow received pulse to a width of approximately three milliseconds. Since the multivibrator is so connected as to blank and prohibit retriggering, this circuit not only converts the incoming data to a standardized pulse shape for use in the later circuitry, but also provides a form of noise inhibitor; under conditions of no signal or very weak signal, where receiver noise becomes dominant due to AGC action, the output pulse stream is held to frequencies of less than 330 Hz. This prohibits saturation of the internal 12-bit binary rate counter, which thus is restricted to only 9-line output. The

output from this multivibrator is also taken to a front panel BNC monitor jack, so that the frequency may be counted by an external counter or observed on an oscilloscope for proper adjustment of the bias control.

An internal crystal-controlled clock provides all required timing. The clock pulses are counted down to 100 and 200 pulse per second rates (for use in the calibration circuit) and then further counted down by decade counters to provide ten and one per second pulses for timing. Conditioned input data pulses are fed as input to a 12-stage binary counter, which is gated open at one second intervals. Parallel 8-line binary data from the counter is latched in a register once per second for conversion to analog form by an 8-bit DAC, and the counter is then immediately reset and a new count interval initiated. The analog output from the DAC is fed through an operational amplifier as a driver to the associated strip-chart recorder, with characteristics such as to provide an output signal of approximately 5 volts for a count rate of 200 per second (expected data rates for the system were 10 to 200 per second). The output displayed is held at the value noted in the previous second while a new count is being made. In the event count rates in excess of 256 per second are detected, indicating noise or false data, the ninth digit from the binary counter is used to disable the data input so that the recorder will not overrange too far. A rotary switch on the front panel permits Operate or Calibrate modes of operation, with calibration available at 0 (grounded input to the counter), 100, or 200 pulses per second (selected from the timing counter described previously).

Output timing signals to the associated recorder are also derived from the internal crystal clock. Two lines from the decade counter which is used to derive the one per second counter gate are mixed by an OR gate in such a way as to provide a 0.2 second wide pulse each time the counter gate is opened, and this signal is available on a separate connector to drive a second pen on the associated recorder. A manual reset button permits the counter system to be synchronized with a display of local or range time, by resetting the counter chain when released. In addition, if range timing is available at the recording position, slow time codes can be connected as input to the system and thus provide both reset at one second intervals and coding by width modulation of the output timing pulses in accord with the input timing. (This circuit may be used with either positive polarity IRIG H time, or tri-level "Slo-code" time signals.)

An internal power supply provides all required operating voltages for the system, deriving the three regulated DC voltages from 50/60 Hz power. The transformer chosen has dual primary windings, permitting operation from either 115 or 230 volt AC sources. A switch internal to the unit permits selection of the proper input voltage, and is fused for 50 watt input.

The data converter was constructed for standard panel mounting in a 19-inch rack, and uses a 3.5 inch high panel. All input and output connections for data, timing, and power are on the rear panel. Three units of this design were built and delivered to personnel from the University of Bonn for use in the MAP/WINE campaign in the winter of 1983/1984.

6.3.3 Azimuth Elevation Data Display

Two types of auxiliary equipment were designed and constructed to "semi-automate" tests of an airborne tracker at the antenna facility at Physical Science Laboratory, New Mexico State University, in Las Cruces, N. Mex. This work was based on experience gained during test and calibration of similar systems used on TEM-1 and TEM-2 of the MSMP program. On earlier tests, the sensor module was placed on an AZ-EL platform mounted on a tower facing another tower which had an X-band source (transmitter). The systems were aligned optically to establish 0oin both axes. Data readout consisted of moving the sensor module to various angles in both axes and reading and recording AGC voltages from the X-band receiver on board the sensor module. Both the angles and error voltages were read and recorded manually. In order to reduce the time required to perform these tests, a method of encoding the angles in digital form was devised. The data from a Scientific Atlanta Synchro-to-Digital resolver were encoded in a Serial PCM form and transmitted to a PCM decoder. The schematic for the encoder is OSU drawing No C43TE01. Data was entered in parallel form (three digit BCD) in both azimuth and elevation and were clocked out along with sync pattern (13 bit Barker code) into a line driver and fed to a standard PCM decoder.

The decoder provided all data in parallel form to a second unit, a digital-to-analog system, which converted data to analog form for each digit on a pen recorder. This D/A system is OSU drawing D43TD01.

At the same time angular data was recorded, the PCM encoder in the sensor module was operated in order to provide real-time error signals from the tracker on the same pen recorder. This provided a real-time display of angles vs error signals and a magnetic tape recorder was used to record both bit streams for reproduction using playbacks.

The two units are shown in Figure 13.

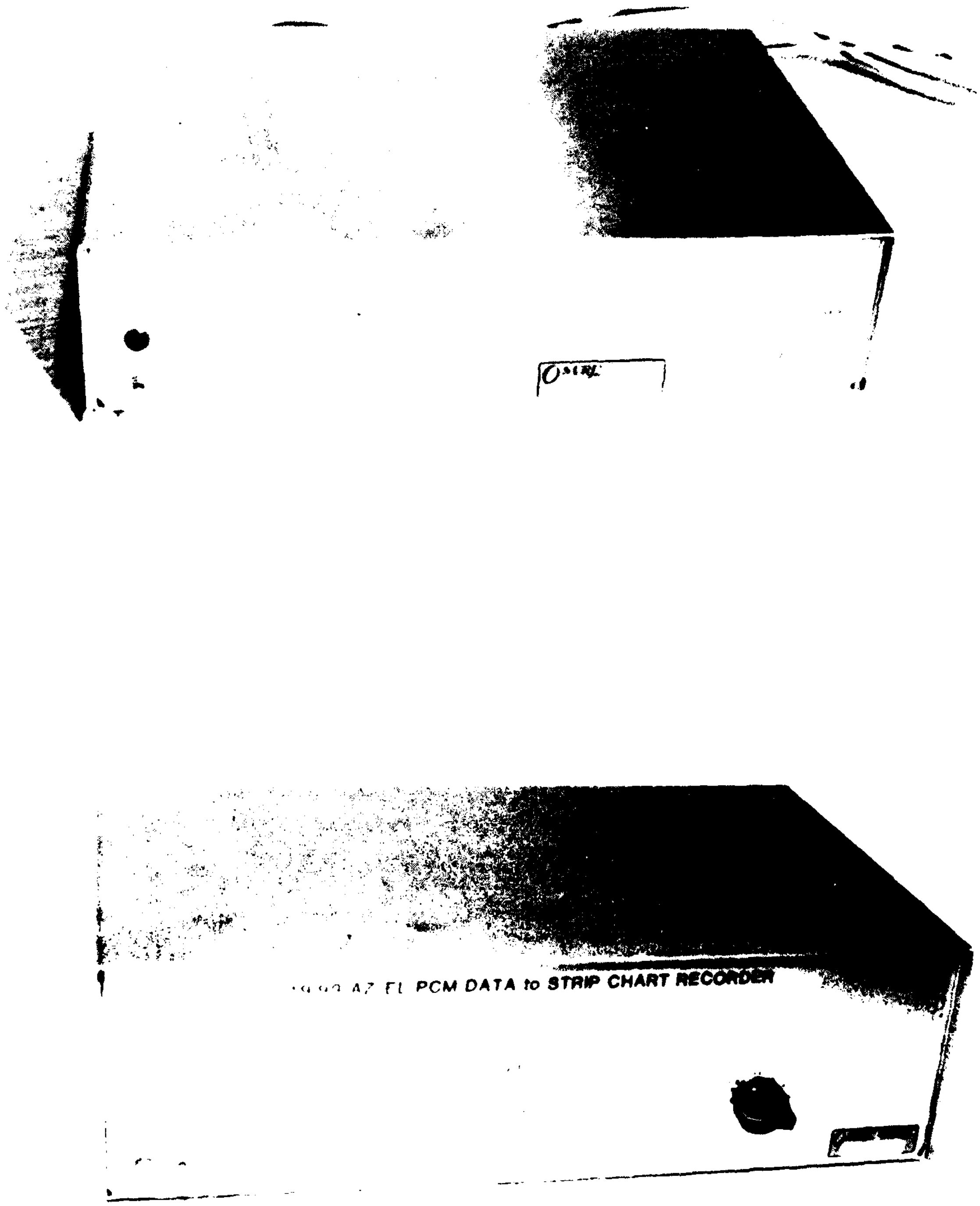


Figure 13 Azimuth Elevation Data Display

7.0 Summary of Results

The purpose of this contract has been to supply engineering and technical support to a program of rocket and balloon research. A very diverse program of contract activities took place, making conclusions and recommendations difficult to outline. However, significant progress has taken place and is described as follows:

7.1 Overall Support Services

Services supplied during this contract period have included studies, conferences, technical coordination, tests, and launch support. The launch support services have included twenty eight different rocket payloads, at eight launch sites. Support has been provided for twenty three balloon launches from five sites. These services have been very diverse in nature, and include provision of airborne equipment such as PCM encoders, timers, entire payload support systems, and provision of ground support equipment and technical personnel. The ground support equipment continues to be more complex as scientific payloads have reached higher technological plateaus and require more accuracy, speed, and resolution of data measurements. Updates of this equipment include modifications to the Minitracker such as changing the reflector size to a six-foot diameter and study of extending the range of the TRADAT system, as well as the addition of a plotter for real-time and playback display of trajectory data. Application of the command capability has taken place successfully, and futher development of this capability is highly recommended. The use of the microcomputers for data selection and display has been investigated, and applications of these systems will take place in the following contract. All of these improvements have been done such that all equipment is transportable aboard standard commercial aircraft.

Methods of testing high-speed, high-resolution PCM telemetry systems have been improved dramatically, using automated methods wherever possible. Some of these methods have been applied to ground-based as well as airborne systems. Continuous study and development are required to retain as well as improve this capability as new equipment and new methods appear.

Special studies have been at the contract monitor's request, such as BERT II feasibility study and studies of high-density digital recording techniques. The LAIRTS program presented a special problem, and even though the program is cancelled, very valuable information was gained regarding storage techniques for large arrays. Miniaturization of airborne systems continue, and the next logical step may be the use of hybrid microcircuits in encoder systems.

7.2 Projects Underway

Ongoing programs include HARP, HIRAM, TAMP, EXCEDE III and SPIRIT as projects where developments at Oklahoma State University may be applied in a following contract. These represent possible application of intervehicle ranging, use of TRADAT and the MINITRACKER, development of airborne PCM encoders, use of command through ranging, and special methods of data display and recording.

7.3 Development Research

The general success of the programs described in this contract has been in large part due to continuing developments using "state-of-the-art" methods. The tendency for more applications of microprocessors in testing and operation of telemetry-related work is an obvious one, and is expected to continue. Control systems for airborne hardware as well as ground support will continue to become computer-related. The staff at the Electronics Laboratory plans to continue efforts to remain capable of providing improved support to Air Force Geophysics Laboratory in following contracts.

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ACRONYMS AND ABBREVIATIONS

	Definition	Ref.
AC	Alternating Current	
ACS	Attitude Control System	
A/D	(or A-to-D) Analog to Digital Converter	PCM
AFGL	Air Force Geophysics Laboratory, Massachusetts	
AGC	Automatic Gain Control	
ANFO	Ammonia Nitrate Fuel Oil	Timer
AM	Amplitude Modulation	
ARR	Andoya Rocket Range, Norway	
AuE	Auroral Energy Program	PFRR
BAC	Ball Aerospace Corporation, Colorado	
BAMM	Balloon Altitude Mosaic Measurements	
BCD	Binary Coded Decimal	PCM
BCS	Booster Control System	SVC
BEAM	Background Equatorial Astronomical Measurements	NRR
BERT	Beam Emission Rocket Test	
BIME	Brazilian Ionospheric Modification Experiment	NRR
BMP	Background Measurement Program	
CAMP	Cold Arctic Mesopause Project	Sphere
CIRRIS	Cryogenic Infrared Radiance Instrumentation for Shuttle	
CLBI	Centro de Lancamentro de Barriera do Inferno	NRR
COPE	Capability for Opportunity Payload Experiments	SCORE
DAC	(or D-to A) Digital to Analog Converter	PCM
DC	Direct Current	
EBC	Energy Budget Campaign	Sphere
ELC	Earth Limb Clutter	BMP
ELIAS	Earth Limb Infrared Atmospheric Structure	PFRR
EPROM	Erasable Programmable Read Only Memory	
FIRSSE	Far Infrared Spectral Survey Experiment	BMP
FM	Frequency Modulation	
FWIF	Field-Widened Interferometer	PFRR
GSE	Ground Support Equipment	
GSFC	Goddard Space Flight Center, Maryland	NASA
HARP	High Altitude Recovery Program	
HDDR	High Density Digital Recording	THIC

HPTEM	High Performance Target Engine Module	MSMP
ID	Identification	PCM
IRBS	Infrared Background Sensor	BMP
IRIG	Inter Range Instrumentation Group	
IRU	Inertial Reference Unit	ACS
Kbps	Kilobits per second	PCM
KHz	Kilo Hertz	
LAIRTS	Large Area Infrared Telescope System	
MAP/WINE	Middle Atmosphere Program/Winter In Northern Europe	Sphere
MADAME	Middle Atmosphere Dynamics and Mesospheric Electrification	MAP/WINE
Mbps	Megabits per second	PCM
MHz	Mega Hertz	
MSB	Most Significant Bit	PCM
MSMP	Multispectral Measurement Program	
MTTS	Mobile Telemetry Tracking System	NASA
NASA	National Aeronautics and Space Administration	
NMSU	New Mexico State University, New Mexico	
NOAA	National Oceanographic & Atmospheric Administration	
NRR	Natal Rocket Range, Brazil	
NRZ-L	Non-return to Zero Level	PCM
NRZ-M	Non-return to Zero Mark	PCM
NRZ-S	Non return to Zero Space	PCM
NU	Northeastern University, Massachusetts	
OSU	Oklahoma State University	
PCM	Pulse Code Modulation	
PFRR	Poker Flats Research Range, Alaska	
PIIE	Polar Ion Irregularity Experiment	
PSL	Physical Science Laboratory, New Mexico	NMSU
RAM	Random Access Memory	
RF	Radio Frequency	
ROM	Read Only Memory	
SBRC	Santa Barbara Research Corporation	
SCORE	Spacecraft Contamination Orbital Research Experiment	
SDC	Space Data Corporation	

SFID	Sub-frame Identification	PCM
SHARP	Stabilized High Altitude Research Platform	
SPE	Solar Proton Event	
SPICE	Survey Probe Infrared Celestial Experiment	
STATE	Structure & Atmospheric Turbulence Environment	Sphere
SVC	Space Vector Corporation	
SYNC	Synchronization; Synchronize	
TAD	Thermal & Atmospheric Dynamics	CAMP
TEM	Target Engine Module	MSMP
THIC	Tape Head Interface Committee	HDDR
TRADAT	Trajectory Data	
TRATEL	Tracking Telemetry	
TV	Television	
USU	Utah State University, Utah	
WFC	Wallops Flight Center, Virginia	NASA
WIT	Wentworth Institute of Technology, Massachusetts	
WSMR	White Sands Missile Range, New Mexico	
ZIP	Zodiacal Infrared Project	BMP

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